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Coastal Inlets Research Program

Data Report: Laboratory Testing of Longshore Sand Transport by Waves and Currents; Morphology Change Behind Headland Structures

Mark B. Gravens and Ping Wang

August 2007

Coastal and Hydraulics Laboratory

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Mark B. Gravens and Ping Wang

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Final report

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Abstract: Data from five series of movable bed laboratory experiments are presented herein. These experiments were conducted in the Large-scale Sediment Transport Facility at the U.S. Army Engineer Research and Development Center, Vicksburg, MS. The data collected from these experiments are being used to improve longshore sand transport relationships under the combined influence of waves and currents and the enhancement of predictive numerical models of beach morphology evolution, in particular, with respect to modeling of tombolo development at detached breakwates and T-groins. These data were instrumental in the development and validation of GENESIS-T (Hanson et al. 2006) an enhanced version of GENESIS that allows for continued simulation of shoreline evolution after tombolo formation at detached breakwaters.

To obtain the data sets collected in these experiments contact Mark B. Gravens (*Mark.B.Gravens@erdc.usace.army.mil*) or 601-634-3809.

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Preface

This report provides a summary of a series of physical model laboratory experiments conducted in the Large-Scale Sediment Transport Facility (LSTF), including the physical model setup, runs, and the data collected. These physical model experiments were conceived and supported by the Coastal Inlets Research Program (CIRP) administered at the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL) under the Navigation Systems Program for Headquaters, U.S. Army Corps of Engineers (HQUSACE). James E. Walker was HQUSACE Navigation Business Line Manager overseeing CIRP. Dr. Jack E. Davis and James E. Clausner, CHL, were the Technical Director and Associate Director, respectively, for the Navigation Systems Program. Dr. Nicholas C. Kraus, Senior Scientists Group (SSG), CHL, was the CIRP Program Manager. Julie D. Rosati, Coastal Processes Branch (CPB), CHL, was the Principle Investigator of the Validation of Predictive Technology at Coastal Inlets work unit responsible for the execution of the experiments.

The mission of CIRP is to conduct applied research to improve USACE capability to manage federally maintained inlets, which are present on all coasts of the United States, including the Atlantic Ocean, Gulf of Mexico, Pacific Ocean, Great Lakes, and U.S. territories. CIRP objectives are to advance knowledge and provide quantitative predictive tools to (a) make management of Federal coastal inlet navigation projects, principally the design, maintenance, and operation of channels and jetties, more effective and reduce the cost of dredging, and (b) preserve the adjacent beach and estuary in a systems approach that treats the inlet and beach together. To achieve these objectives, CIRP is organized in work units conducting research and development in hydrodynamic, sediment transport and morphology change modeling; navigation channels and adjacent beaches; inlet structures and scour; laboratory and field investigations; and technology transfer.

This report was prepared by Mark B. Gravens, CPB, CHL, and Dr. Ping Wang, Department of Geology, University of South Florida. Dr. Kraus, SSG, CHL, provided technical direction, guidance, and consistent motivation for the study. Work was performed under the general

administrative supervision of Thomas W. Richardson, Director, CHL, and Dr. William D. Martin, Deputy Director, CHL.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
square miles	2.589998 E+06	square meters

1 Introduction

Five series of movable bed physical model experiments were conducted in the Coastal and Hydraulics Laboratory's (CHL's) Large-Scale Sediment Transport Facility (LSTF) basin (Hamilton et al. 2001). The first three series of experiments were conducted over the period June 2003 through January 2004. The fourth and fifth series of experiments were conducted over the period October 2004 through December 2004. These experiments were performed as one component of the Validation of Predictive Technology at Coastal Inlets work unit of the Coastal Inlets Research Program (CIRP). The purpose of the experiments was to gather quality data sets for testing and validation of new sediment transport relationships (Hanson et al. 2001) and numerical model algorithms for the development of tombolos in the lee of headland structures (detached nearshore breakwaters and T-head groins) (Hanson et al. 2006). Each series of experiments was made up of several runs or cases in which waves and currents were generated in the model basin and hydrodynamic data were collected. Between cases, beach profiles were surveyed and in some instances the sediment traps were cleaned and the beach profile was reconstructed to the equilibrium profile.

The first series of experiments were aimed at generating data sets for testing and validation of sediment transport relationships for sand transport in the presence of waves and currents. These experiments, referred to as "Base" experiments, were executed in a series of five runs of approximately 160 min each on a natural beach (no structures) in the LSTF. The initial condition for these runs consisted of a uniform beach profile constructed to a known "equilibrium" profile consistent with the incident wave condition and sediment grain size.

The second and third series of experiments were designed to generate data sets for testing and validation of numerical model algorithms for development of tombolos in the lee of detached nearshore breakwaters. These experiments, referred to as "Test 1" and "Test 2," were executed in a series of 16 runs (eight runs for each test series), of approximately 190 min each on a natural beach with a 4-m-long rubble-mound breakwater centrally located in the alongshore direction of the model beach and positioned 4 m offshore of the initial shoreline (Figure 1).

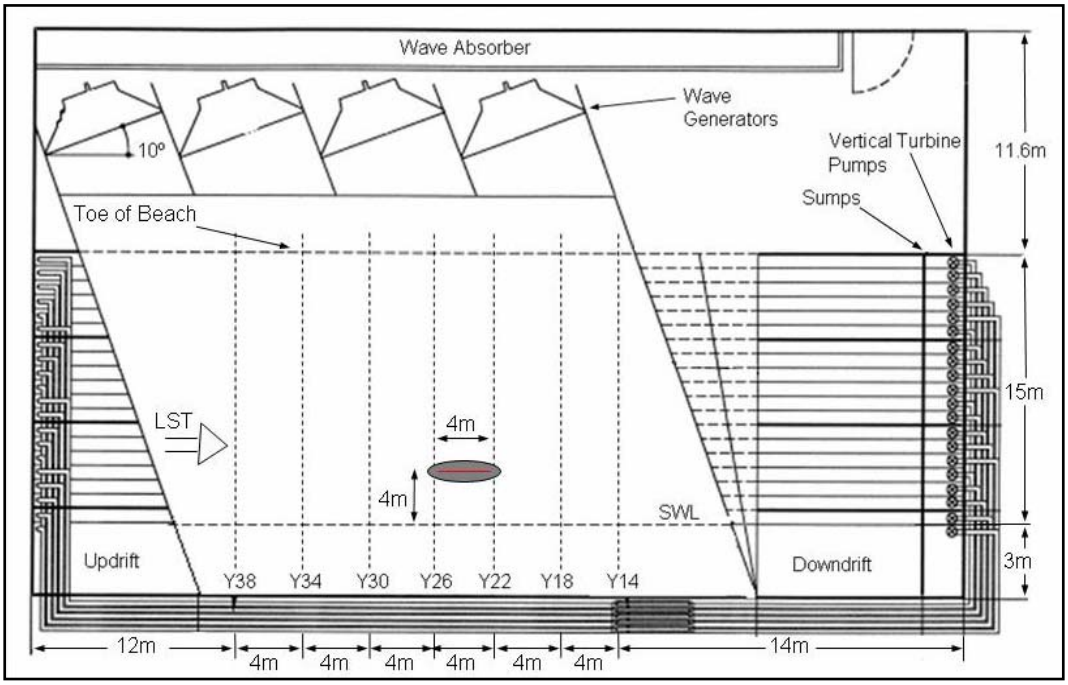


Figure 1. Breakwater layout within LSTF (Test 1 and Test 2).

The fourth series of experiments, referred to as "Test 3," investigated tombolo development in the lee of a T-head groin. The Test 3 experiments were executed in a series of six runs of approximately 180 min each on a natural beach with a T-head groin with a 4-m-long shore-parallel head section (positioned in the same location as the breakwater in Tests 1 and 2) with a centrally positioned shore-connected stem section (Figure 2).

The fifth series of experiments, referred to as "Test 4" investigated tombolo development in the lee of a 3-m-long rubble-mound breakwater positioned 1.5 m offshore of the initial shoreline (Figure 3). These experiments were conducted in a series of four runs of approximately 180 min each.

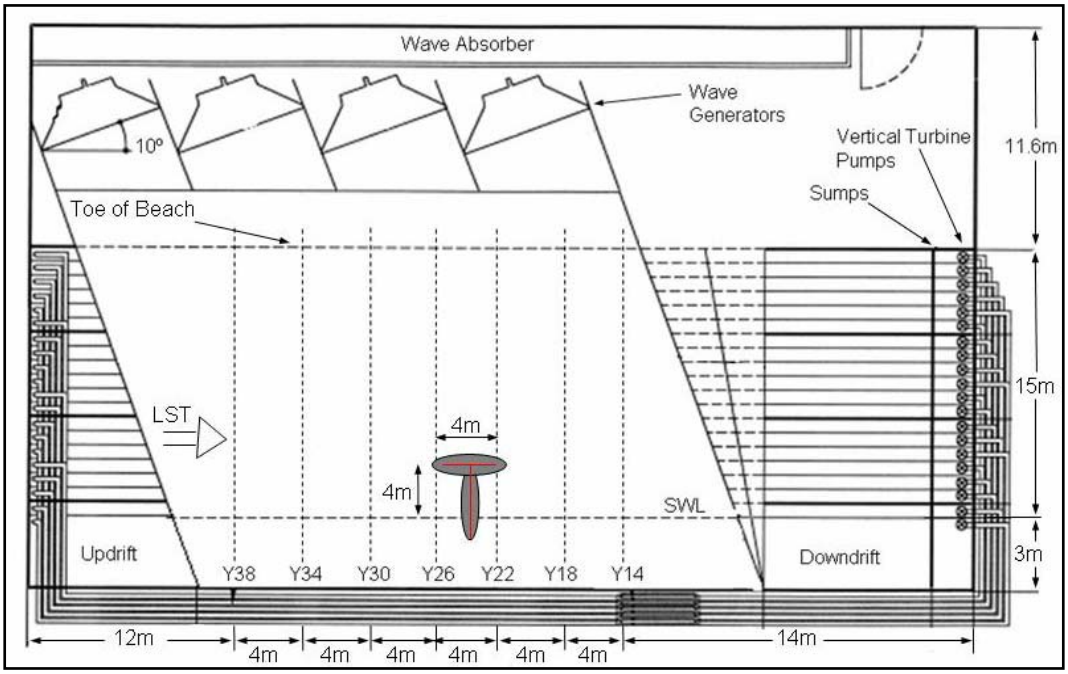


Figure 2. T-Groin layout within LSTF (Test 3).

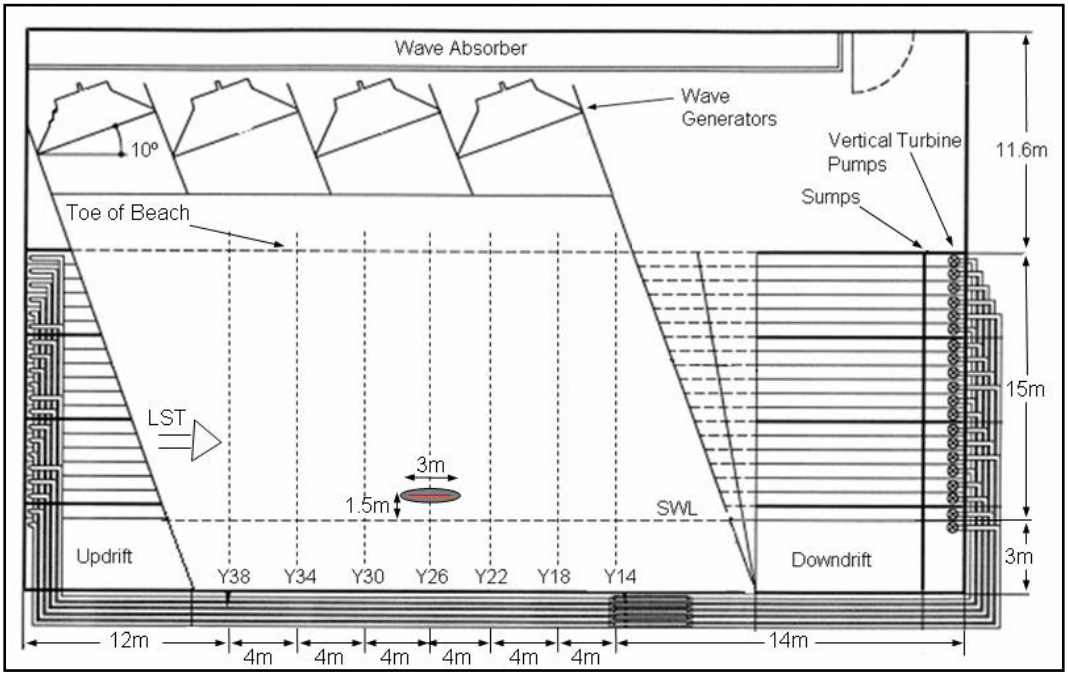


Figure 3. Nearshore breakwater layout within LSTF (Test 4).

In all runs, the four wave generators were programmed to generate a spilling breaking wave condition characterized by a 0.26-m significant breaking wave height, a 1.5-sec period and an approximate breaking wave angle of 6.5 deg with respect to the shoreline. Measurements of wave height, wave period, longshore cross-shore and vertical current velocity,

and sediment concentration data were obtained with instruments mounted on the LSTF instrumentation bridge, which could be positioned at any longshore location. These data were collected at 11 alongshore positions in the Base experiments, at 13 alongshore positions in the Test 1, Test 2, and Test 3 experiments, and at 14 alongshore positions in the Test 4 experiments. The wave and current data were collected over 10-min sampling intervals at each of the alongshore positions. The magnitude and cross-shore distribution of sand transported along the beach were collected and measured in 20 gravity-feed sediment traps located at the downdrift end of the moveable bed model beach. Beach profiles were surveyed by rod and acoustic survey techniques after each run. The spacing between beach profiles varied between 0.25 and 4 m depending on proximity to the headland structure. The beach profile data were processed and archived using the Beach Morphology Analysis Package, BMAP, software (Sommerfeld et al. 1994). The sediment comprising the beach in the LSTF is very well-sorted quartz sand with a median grain size 0f 0.15 mm.

Base

In Base Case 1 (B_C1), the longshore flux of water produced by the wave-driven longshore current was recirculated from the downstream end to the upstream end of the model beach using the LSTF's external recirculation system. In Base Case 2 (B_C2), an external longshore current, in addition to the waves and wave-driven longshore current, was imposed across the model beach by recirculating twice the wave-generated longshore flux of water. This procedure produced an imposed longshore current varying between 5 and 10 cm/sec across the surf zone. Base Case 3 (B_C3) involved recirculating twice the wave-generated longshore flux of water but, in this run, the wave generators were not operated, producing a current-only condition. In Base Case 4 (B_C4), the recirculation system was again operated to impose an external longshore current across the model beach in addition to the waves and wave-driven longshore current by recirculating one and a half times the wave-generated longshore flux of water. The imposed longshore current in this run varied between about 2 and 5 cm/sec across the surf zone. Base Case 5 (B_C5) was a repeat of the experimental setup of Base Case 4. This experiment was conducted to investigate the influence the antecedent bed forms (ripples) may have had on the results of Base Case 4.

Test 1

In the Test 1 series of experiments (T1C1 through T1C8), the longshore flux of water produced by the wave-driven longshore current was recirculated from the downstream end to the upstream end of the model beach using the LSTF's external recirculation system. After runs T1C2 (t = 6 hr) and T1C5 (t = 15 hr) the sediment traps were dredged and the beach, one structure length (4 m) updrift of the breakwater, was rebuilt to the equilibrium template. Tombolo formation was observed after run T1C8 (t = 24 hr).

Test 2

In the Test 2 series of experiments (T2C1 through T2C8), an external longshore current was imposed across the model beach by recirculating twice the longshore wave-generated flux of water (twice the volume of water recirculated in the Test 1 experiments). Due to the imposed external current, longshore sand transport rates and consequently sediment volume collected in the sediment traps were greater than that in the Test 1 series of runs. In this test series, the sediment traps were dredged and the updrift beach beyond one structure length updrift of the breakwater (4 m) was rebuilt to the equilibrium template after runs T2C2 (t = 6 hr), T2C4 (t = 12 hr), and T2C6 (t = 18 hr). After run T2C8 the salient had advanced seaward to within about 10 cm of the breakwater.

Test 3

In the Test 3 series of experiments (T3C1 through T3C6) the longshore flux of water produced by the wave-driven longshore current was recirculated from the downstream end to the upstream end of the model basin using the LSTF's external recirculation system. The sediment traps were dredged, and the beach, one structure length updrift of the T-groin (4 m), was rebuilt to the equilibrium template after runs T3C2 (t = 6 hr) and T3C4 (t = 12 hr). The sailent updrift of the T-groin stem advanced to the head section of the groin after run T3C4 (t = 12 hr).

Test 4

In the Test 4 series of experiments (T4C1 through T4C4) the longshore flux of water produced by the wave-driven longshore current was recirculated from the downstream end to the upstream end of the model basin using the LSTF's external recirculation system. The sediment traps

were dredged, and the updrift beach beyond one structure length updrift of the breakwater (3 m) was rebuilt to the equilibrium template after run T4C2 (t = 6 hr). The sailent in the lee of the breakwater advanced to the breakwater during the first run (T4C1, t = 3 hr).

The following chapters describe the experimental setup and execution of each of the experiments and provide a listing and plots of the data sets collected.

2 Base Experiments

The Base series of experiments were performed to assemble data sets for testing and validation of new sediment transport relationships for sand transport in the presence of waves and currents. These experiments were executed in a series of four runs of approximately 160 min each on a natural beach in the LSTF. The initial condition for these runs consisted of a uniform beach profile constructed to a known equilibrium profile consistent with the incident wave condition. This chapter describes each of the Base runs and provides a summary of the available data sets for this series of experiments.

B_C1

In Base Case 1 (B_C1), the longshore flux of water produced by the wave-driven longshore current was recirculated from the downstream end to the upstream end of the model beach using the LSTF's external recirculation system. This case involved a 165-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at 11 cross-shore transects (2-m intervals between alongshore position 14 and 34, see Figure 1 for alongshore locations). The data for this run are compiled in eight files as follows:

1. B_C1pre.BM (BMAP file, pre-run survey 6 profile lines).
2. B_C1.BM (BMAP file, post-run survey 12 profile lines).
3. B_C1p.xyz (ASCII file, pre-run survey data xyz format).
4. B_C1.xyz (ASCII file, post-run survey data xyz format).
5. B_C1_current_summary.xls (Excel file, current data).
6. B_C1_wave_summary.xls (Excel file, wave data).
7. B_C1_fobs_summary.xls (Excel file, sediment concentration data).
8. B_C1_trap_summary.xls (Excel file, sediment trap data).

Figures 4 and 5 provide images of digital terrain models (DTM) based on the pre- and post-run survey data sets. The average measured cross-shore distribution of the longshore current is plotted in Figure 6 and the cross-shore distribution of the average measured significant wave height is plotted in Figure 7. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 8.

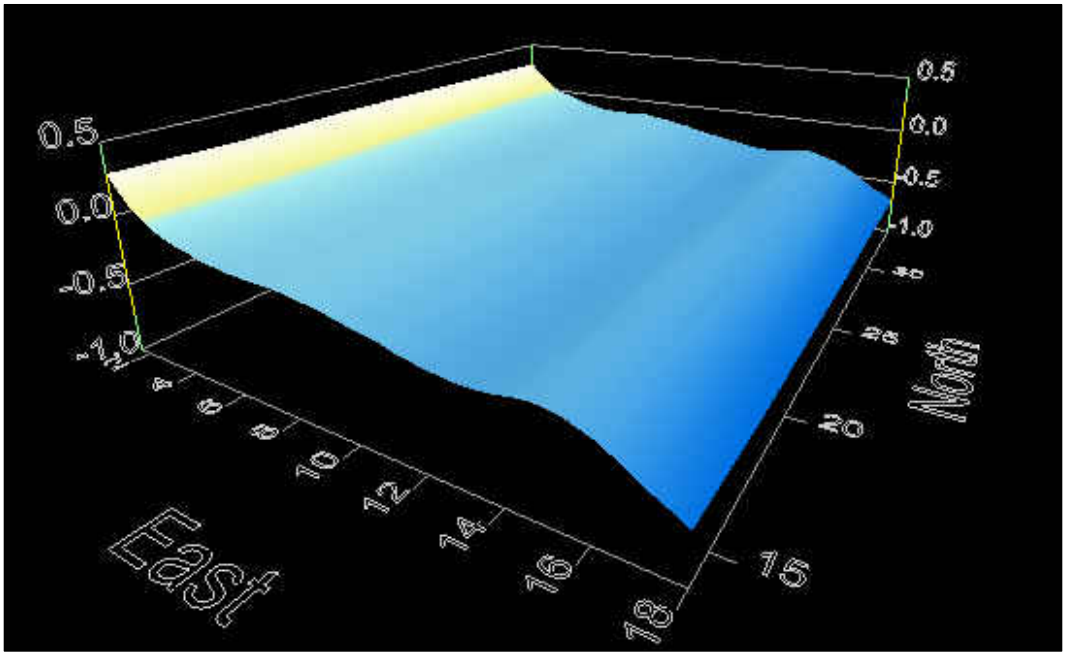


Figure 4. Initial condition model beach, B_C1.

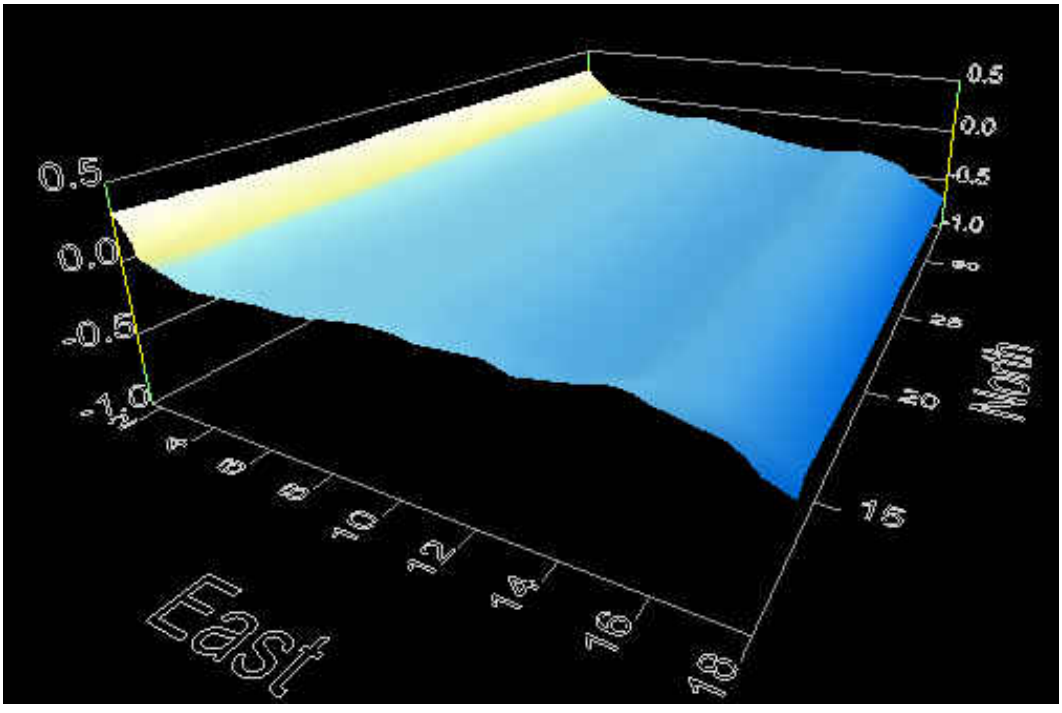


Figure 5. Post-run model beach, B_C1.

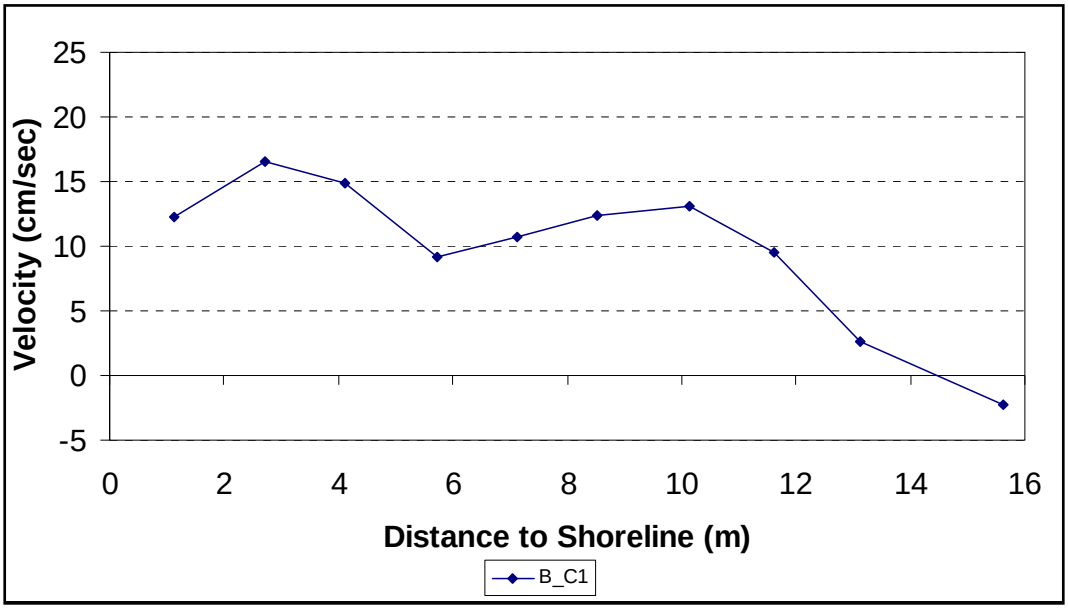


Figure 6. Cross-shore distribution of longshore current, B_C1.

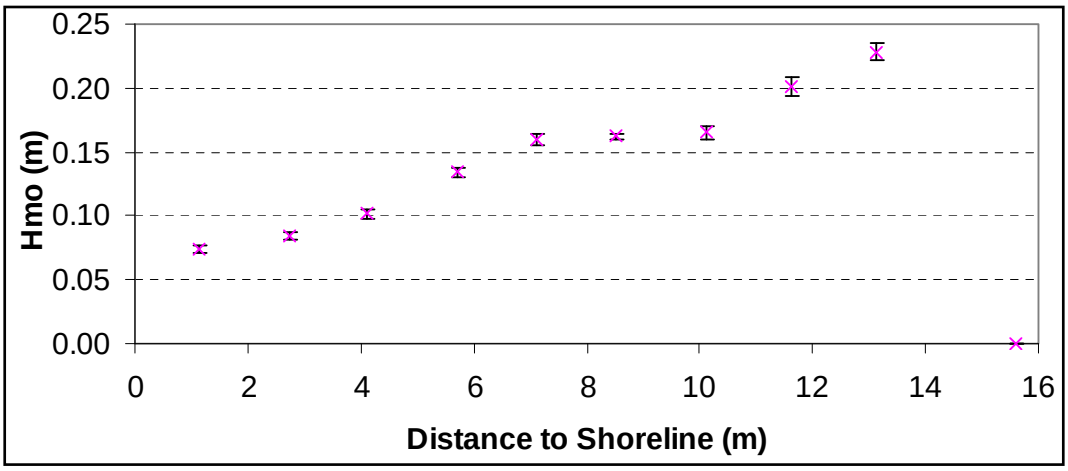


Figure 7. Cross-shore distribution of wave height, B_C1.

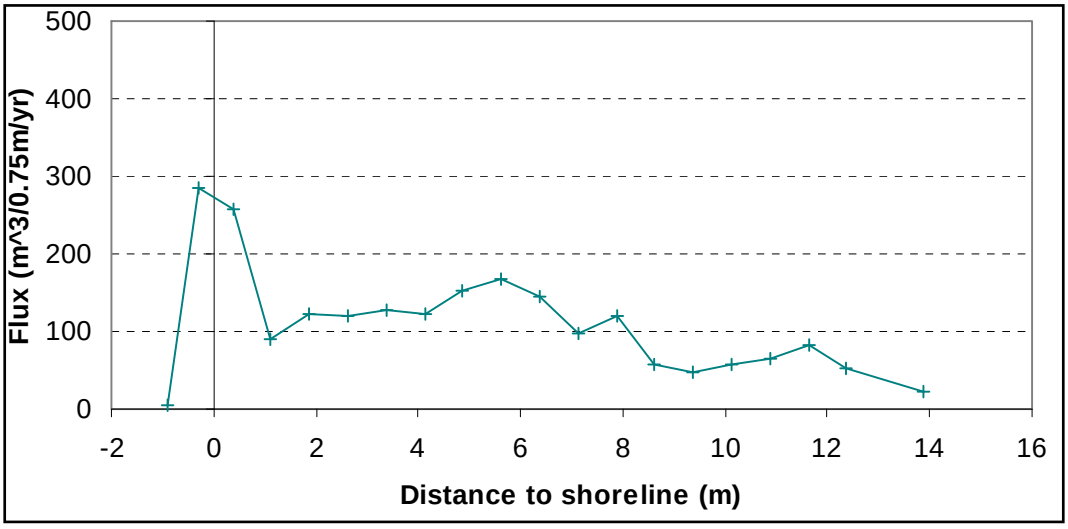


Figure 8. Cross-shore distribution of longshore sediment flux, B_C1.

B_C2

In Base Case 2 (B_C2), an external longshore current was imposed across the model beach in addition to the waves and wave-driven longshore current. This was achieved by recirculating double the estimated wave-generated longshore flux of water. This procedure produced an imposed longshore current varying between 5 and 10 cm/sec across the surf zone. The duration of the B_C2 run was 150 min. Wave, current, and sediment concentration measurements were made at 11 cross-shore transects along the model beach (2 m alongshore intervals between alongshore position 14 and 34) during the run. The data for this run are compiled in six files as follows:

1. B_C2.BM (BMAP file, post-run survey 12 profile lines).
2. B_C2.xyz (ASCII file, post-run survey data xyz format).
3. B_C2_current_summary.xls (Excel file, current data).
4. B_C2_wave_summary.xls (Excel file, wave data).
5. B_C2_fobs_summary.xls (Excel file, sediment concentration data).
6. B_C2_trap_summary.xls (Excel file, sediment trap data).

The initial condition for run B_C2 was post-run B_C1 (Figure 5). The post-run B_C2 model beach DTM is illustrated in Figure 9. The average measured cross-shore distribution of the longshore current is plotted in Figure 10. Also plotted in Figure 10 is the imposed external longshore current. This curve was obtained by subtracting the B_C1 measured longshore current (Figure 6) from the B_C2 measured longshore current.

The cross-shore distribution of the average measured significant wave height is plotted in Figure 11. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 12.

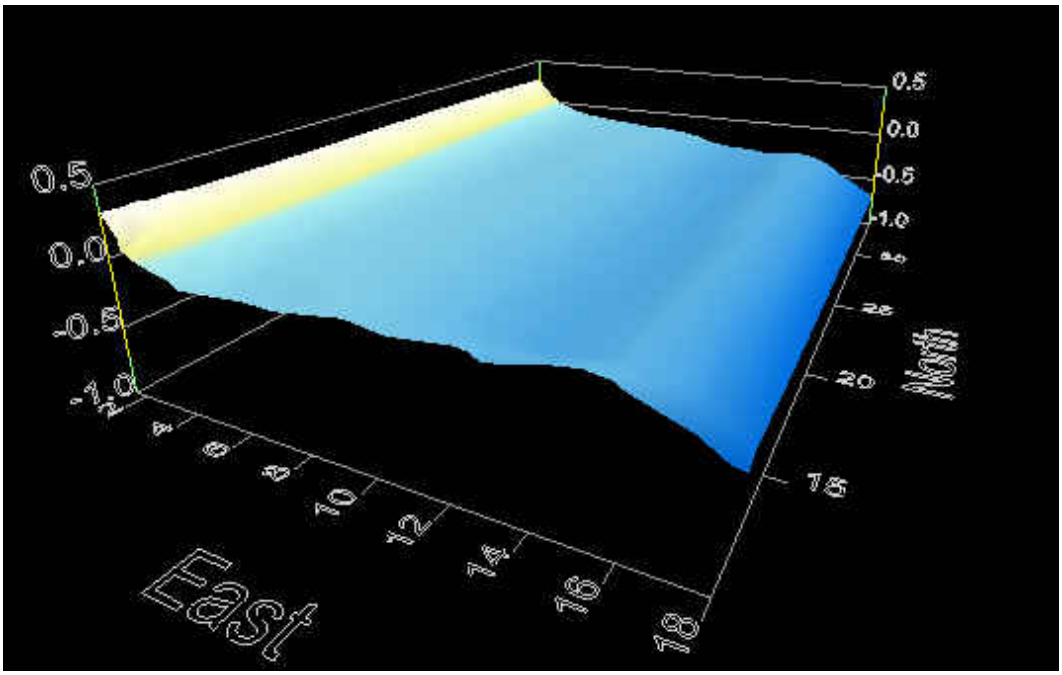


Figure 9. Post-run model beach, B_C2.

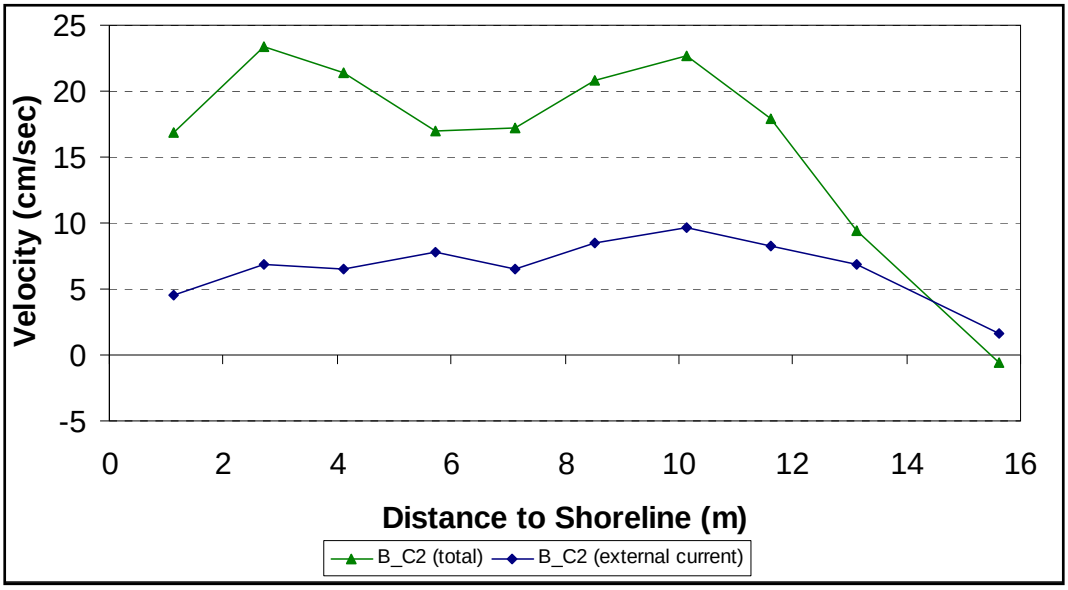


Figure 10. Cross-shore distribution of longshore current, B_C2.

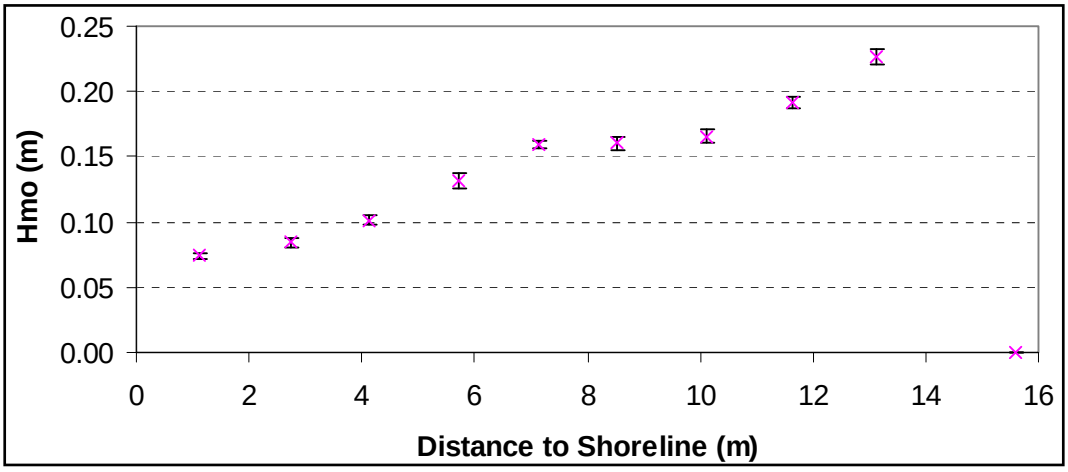


Figure 11. Cross-shore distribution of wave height, B_C2.

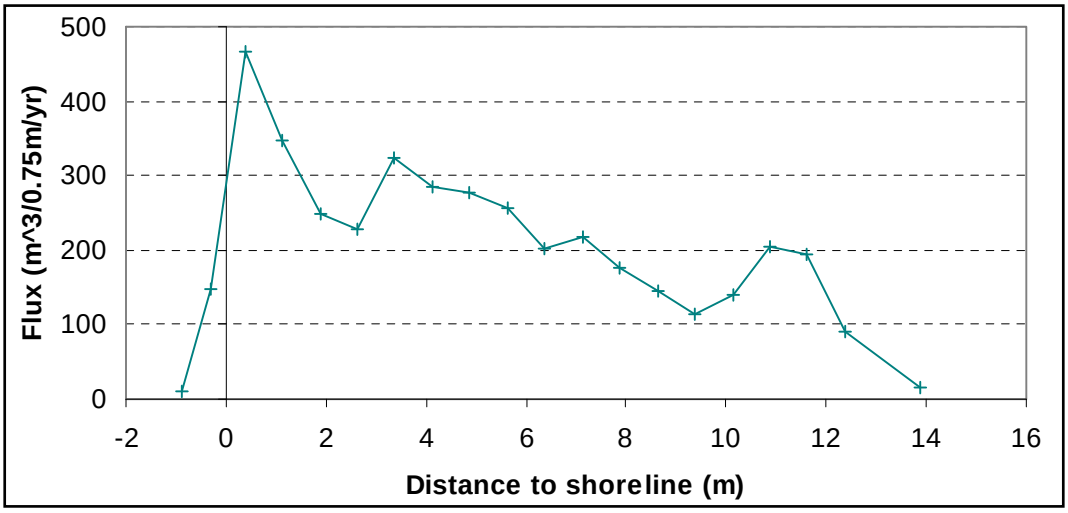


Figure 12. Cross-shore distribution of longshore sediment flux, B_C2.

B_C3

In Base Case 3 (B_C3), the LSTF's longshore current recirculation system was operated to recirculate double the estimated wave-generated longshore flux of water. For this run, the wave generators were not operated producing strong longshore currents (approximately equal to run B_C2, Figure 10), but without the stirring action of breaking waves. The duration of the B_C3 run was 195 min. Wave, current, and sediment concentration measurements were made at 11 cross-shore transects (2 m intervals between alongshore positions 14 and 34) during the run. The data for this run are compiled in seven files as follows:

1. B_C3pre.BM (BMAP file, pre-run survey 29 profile lines).
2. B_C3.BM (BMAP file, post-run survey 29 profile lines).

3. B_C3p.xyz (ASCII file, pre-run survey data xyz format).
4. B_C3.xyz (ASCII file, post-run survey data xyz format).
5. B_C3_current_summary.xls (Excel file, current data).
6. B_C3_wave_summary.xls (Excel file, wave data).
7. B_C3 Trap_summary.xls (Excel file, sediment trap data).

Because this run did not involve the stirring action of breaking wave conditions the fiber optic backscatter sensors (FOBS) did not record meaningful returns for the sampling conducted. Consequently, the FOBS data were not archived for this run. Figures 13 and 14 provide images of pre- and post-run DTMs of the model beach based on the profile survey data. The average measured cross-shore distribution of the longshore current is plotted in Figure 15. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 16.

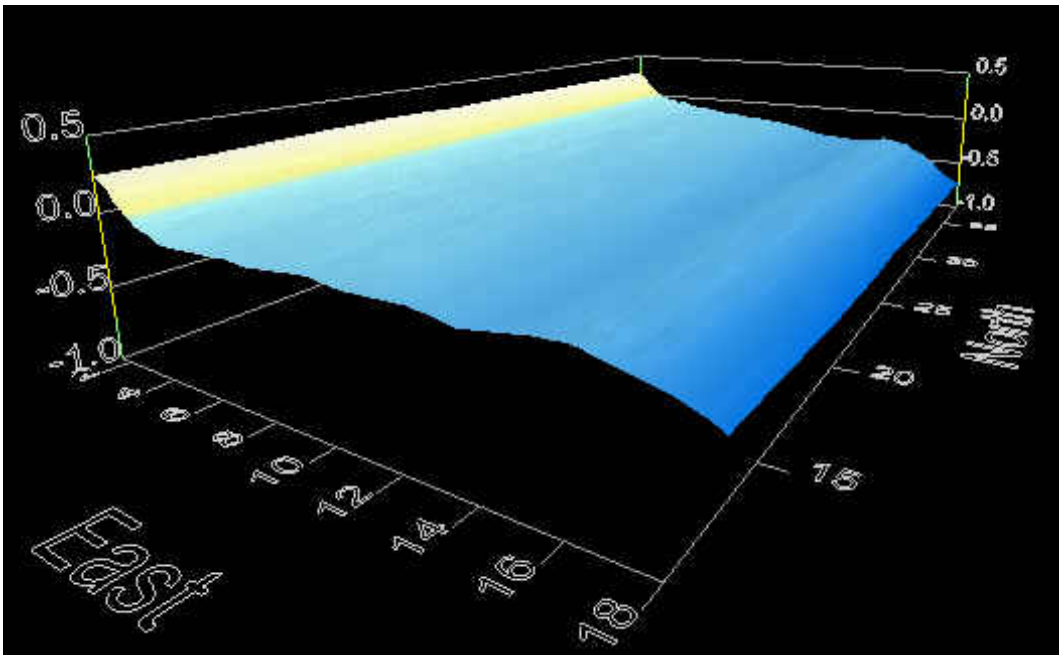


Figure 13. Pre-run model beach, B_C3.

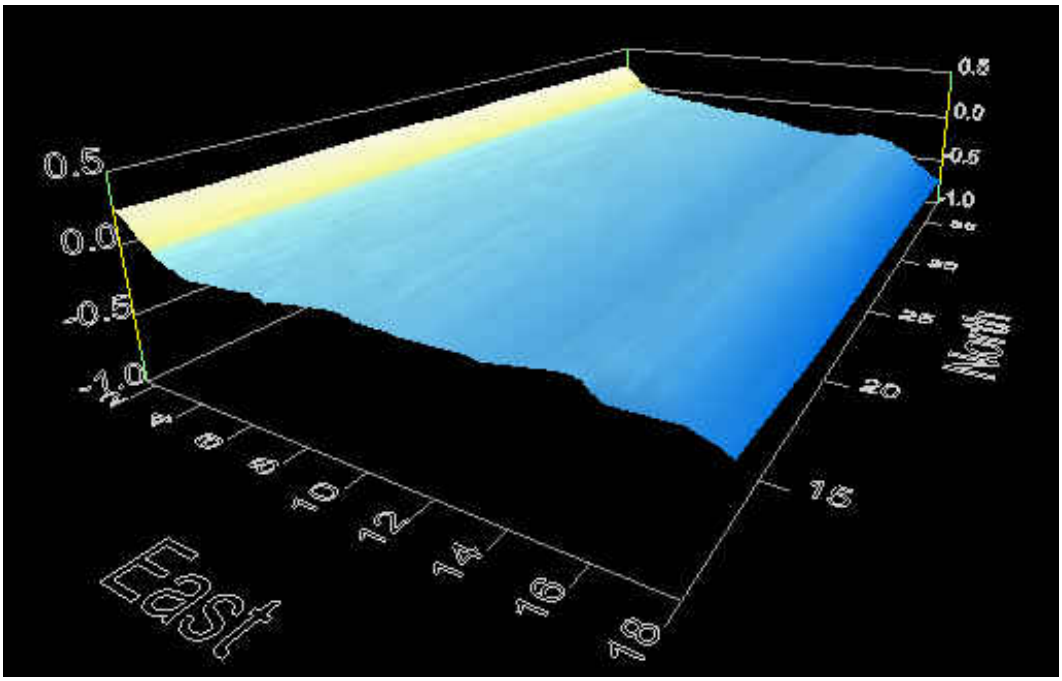


Figure 14. Post-run model beach, B_C3.

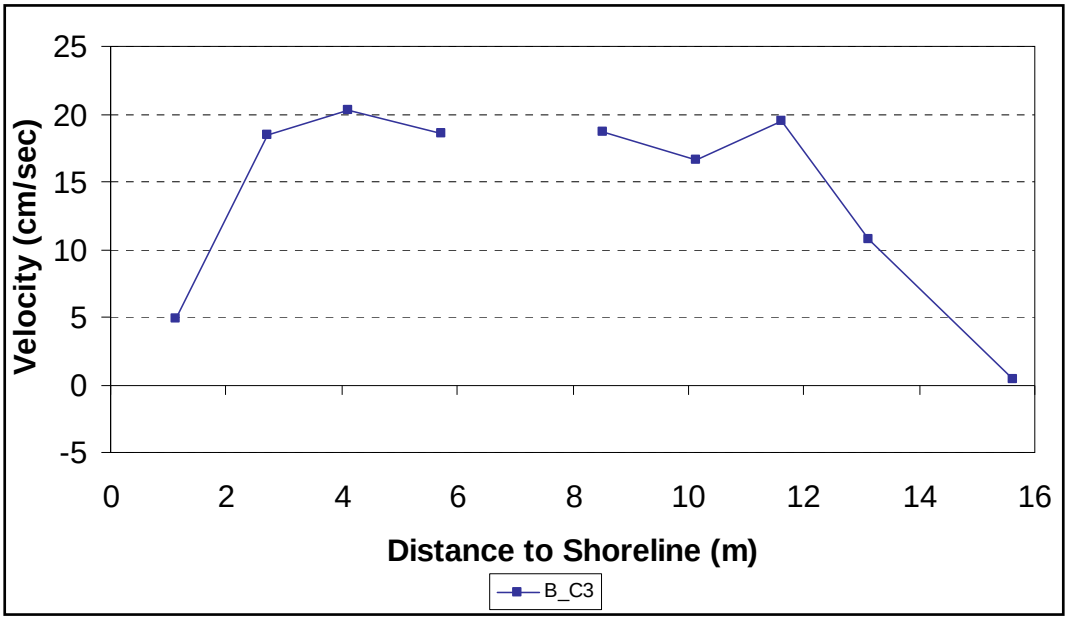


Figure 15. Cross-shore distribution of longshore current, B_C3.

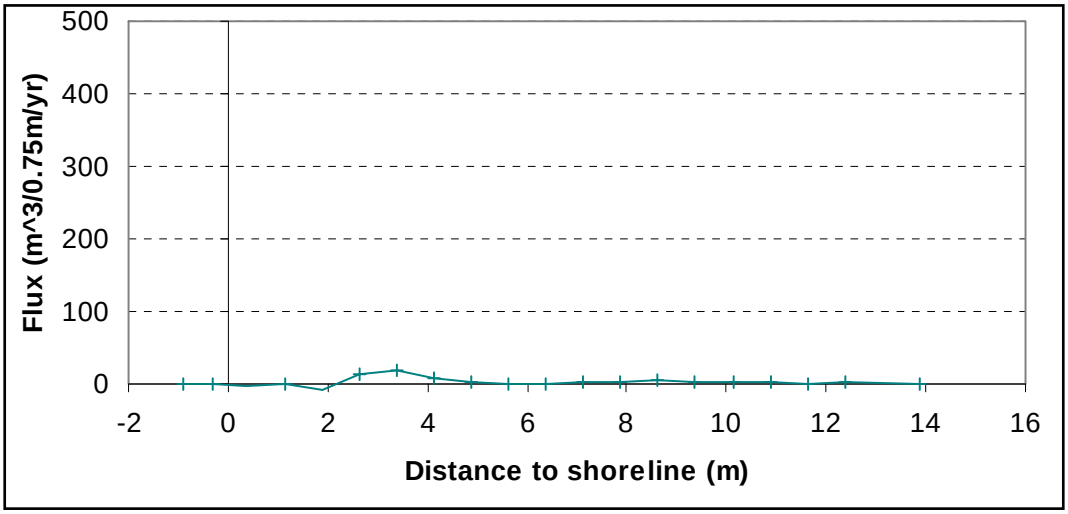


Figure 16. Cross-shore distribution of longshore sediment flux, B_C3.

B_C4

In Base Case 4 (B_C4), the recirculation system was again operated to impose an external longshore current across the model beach in addition to the waves and wave-driven longshore current. In this run, one and a half times the estimated wave-generated longshore flux of water was recirculated using the LSTF's longshore current recirculation system. The resulting imposed external current varied between about 2 and 5 cm/sec across the surf zone. The duration of the B_C4 run was 148 min. Wave, current and sediment concentration measurements were made at 11 cross-shore transects along the model beach (2 m alongshore intervals between alongshore position 14 and 34) during the run. The data for this run are compiled in six files as follows:

1. B_C4.BM (BMAP file, post-run survey 29 profile lines).
2. B_C4.xyz (ASCII file, post-run survey data xyz format).
3. B_C2_current_summary.xls (Excel file, current data).
4. B_C2_wave_summary.xls (Excel file, wave data).
5. B_C2_fobs_summary.xls (Excel file, sediment concentration data).
6. B_C2_trap_summary.xls (Excel file, sediment trap data).

The initial condition for run B_C4 was post-run B_C3 (Figure 14). The post-run B_C4 model beach DTM is illustrated in Figure 17. The average measured cross-shore distribution of the longshore current is plotted in Figure 18. Also plotted in Figure 18 is the imposed external longshore current. This curve was obtained by subtracting the B_C1 measured longshore current (Figure 6) from the B_C4 measured longshore current.

The cross-shore distribution of the average measured significant wave height is plotted in Figure 19. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 20.

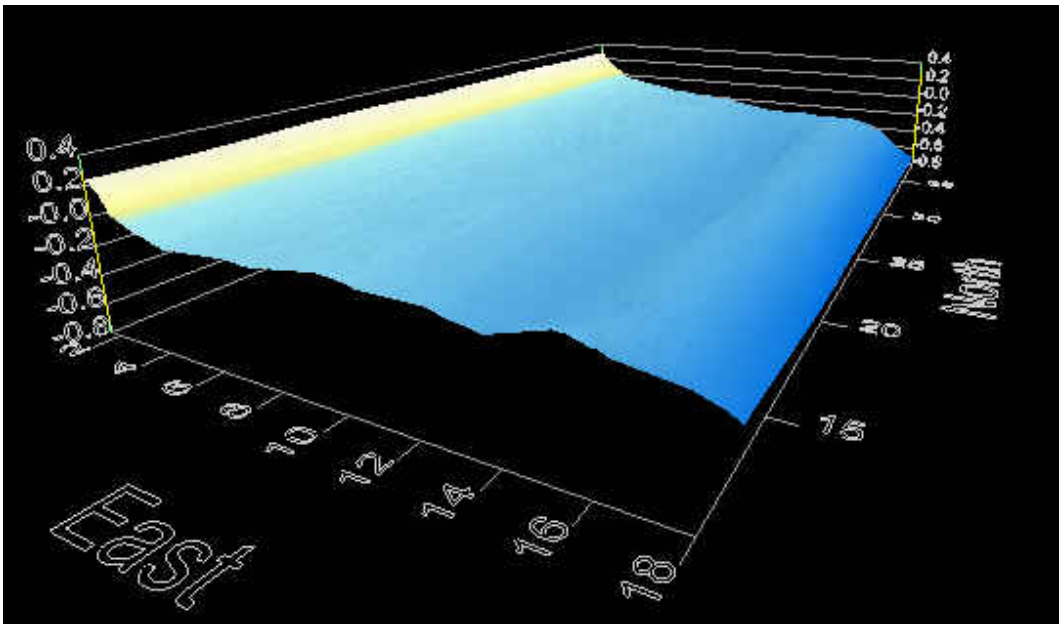


Figure 17. Post-run model beach, B_C4.

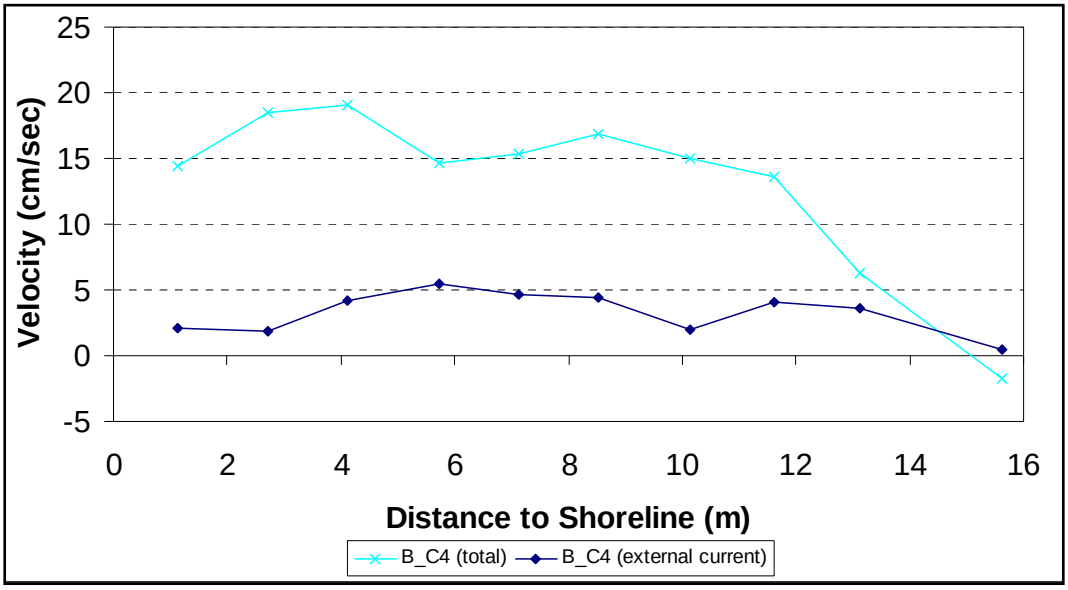


Figure 18. Cross-shore distribution of longshore current, B_C4.

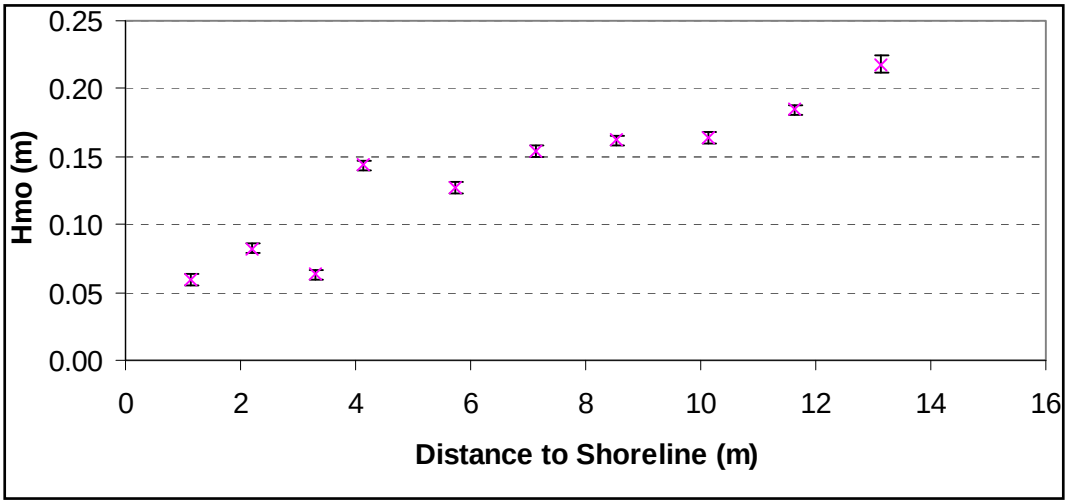


Figure 19. Cross-shore distribution of wave height, B_C4.

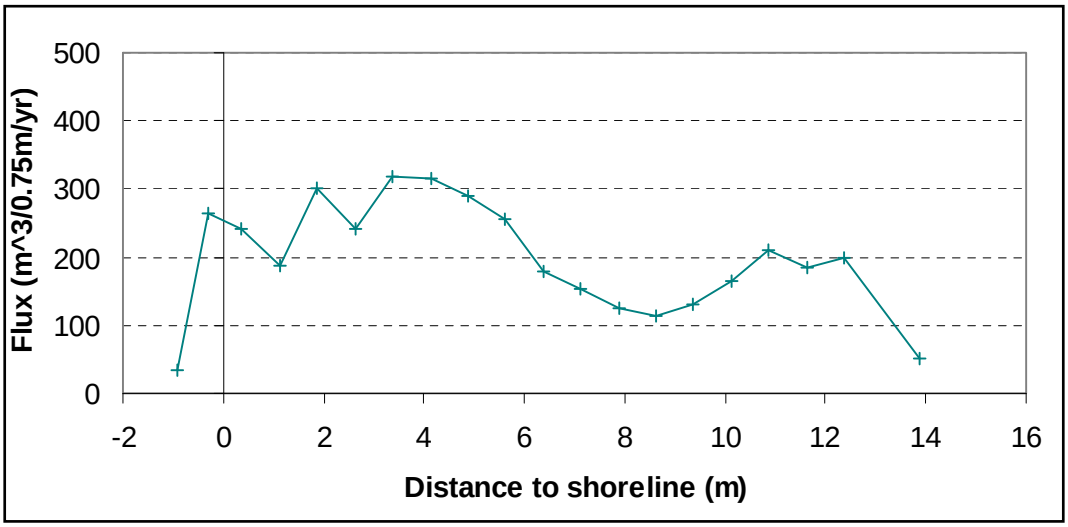


Figure 20. Cross-shore distribution of longshore sediment flux, B_C4.

B_C5

In Base Case 5 (B_C5), the recirculation system was again operated to impose an external longshore current across the model beach in addition to the waves and wave-driven longshore current. In this run, one and a half times the estimated wave-generated longshore flux of water was recirculated by the LSTF's longshore current recirculation system. This experiment was conducted to determine the possible influence the antecedent bedforms (shore-perpendicular ripples) may have had on the results of Base Case 4. Recall that the initial condition for experiment Base Case 4 was the final condition for Base Case 3, which involved recirculation of double the estimated wave-generated flux of water without

waves. This forcing left the LSTF bed with a rippled bed form that was oriented perpendicular to the shoreline. The longshore sediment flux in Base Case 4 was measured at approximately 97 percent of the total longshore sediment flux measured in Base Case 2. It was speculated that the observed reorientation of the bed forms could have been responsible for the higher than expected sediment flux.

The imposed external current for experiment Base Case 5 varied between about 2 and 5 cm/sec across the surf zone. It is noted that the Acoustic Doppler Velocimeter positioned approximately 10 m seaward of the shoreline recorded an imposed current of nearly 10 cm/sec, but the quality that instrument's readings are suspect for this run. The duration of the B_C5 run was 150 min. Wave, current, and sediment concentration measurements were made at 11 cross-shore transects along the model beach (2 m alongshore intervals between alongshore position 14 and 34) during the run. The data for this run are compiled in seven files as follows:

1. B_C5pre.BM (BMAP file, pre-run survey 27 profile lines).
2. B_C5.BM (BMAP file, post-run survey 27 profile lines).
3. B_C5pre.xyz (ASCII file, pre-run survey data xyz format).
4. B_C5.xyz (ASCII file, post-run survey data xyz format).
5. B_C5_current_summary.xls (Excel file, current data).
6. B_C5_wave_summary.xls (Excel file, wave data).
7. B_C5_trap_summary.xls (Excel file, sediment trap data).

The initial condition model beach DTM for run B_C5 is illustrated in Figure 21. The post-run B_C5 model beach DTM is illustrated in Figure 22. The average measured cross-shore distribution of the longshore current is plotted in Figure 23. Also plotted in Figure 23 is the imposed external longshore current. This curve was obtained by subtracting the B_C1 measured longshore current (Figure 6) from the B_C5 measured longshore current. The cross-shore distribution of the average measured significant wave height is plotted in Figure 24. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 25. Here it is observed that the measured flux of longshore sediment transport was again nearly equal to that measured for B_C2, indicating that the antecedent bed forms were not responsible for the larger than anticipated longshore sediment transport rate.

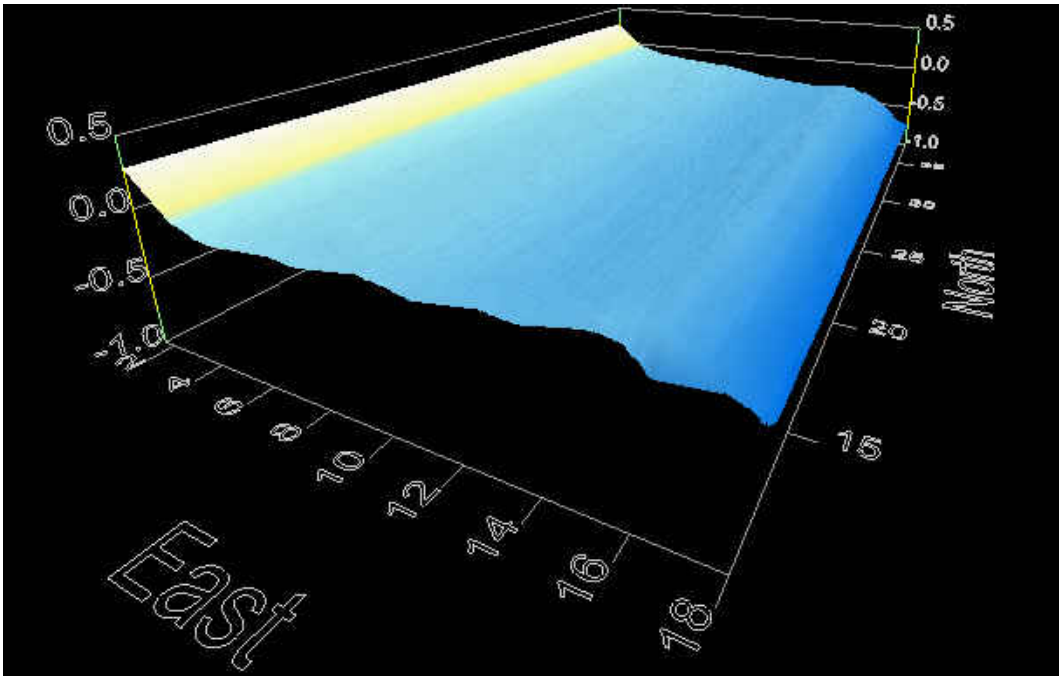


Figure 21. Initial condition model beach, B_C5.

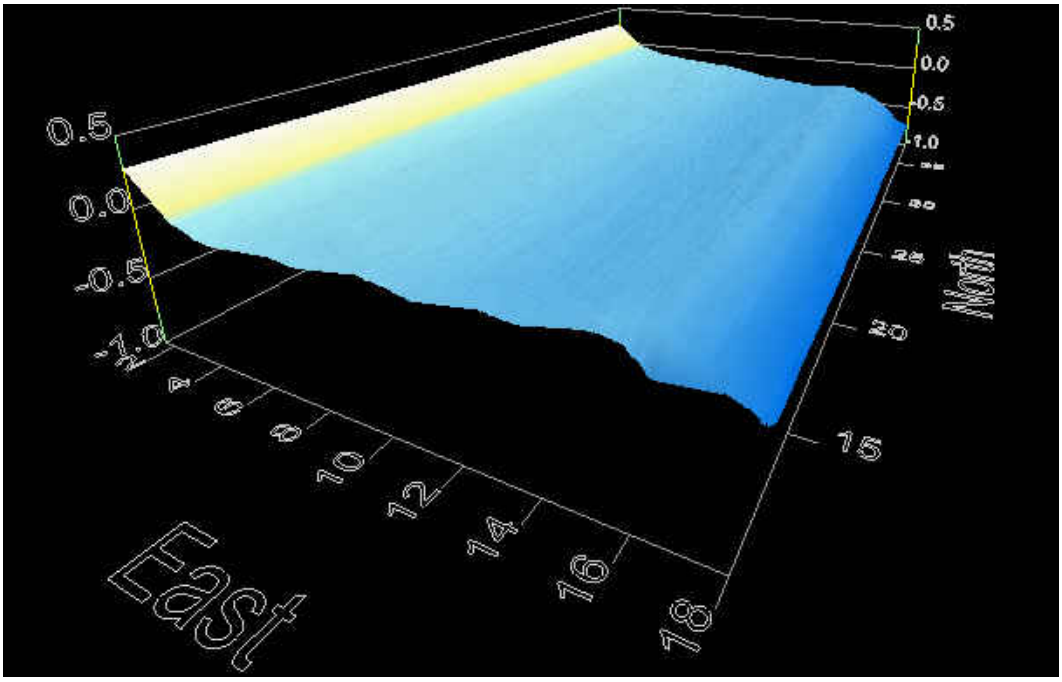


Figure 22. Post-run model beach, B_C5.

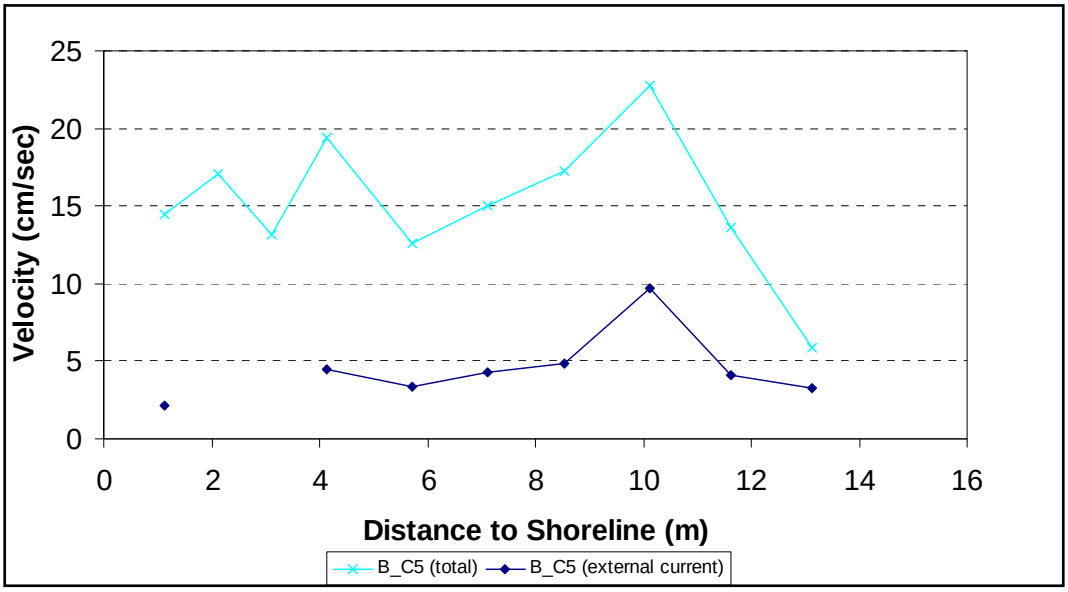


Figure 23. Cross-shore distribution of longshore current, B_C5.

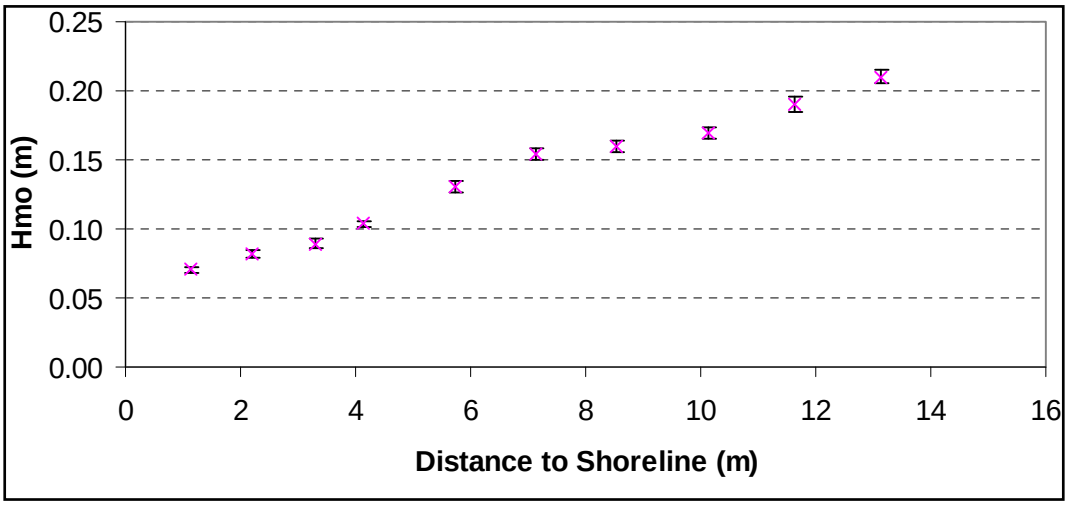


Figure 24. Cross-shore distribution of wave height, B_C5.

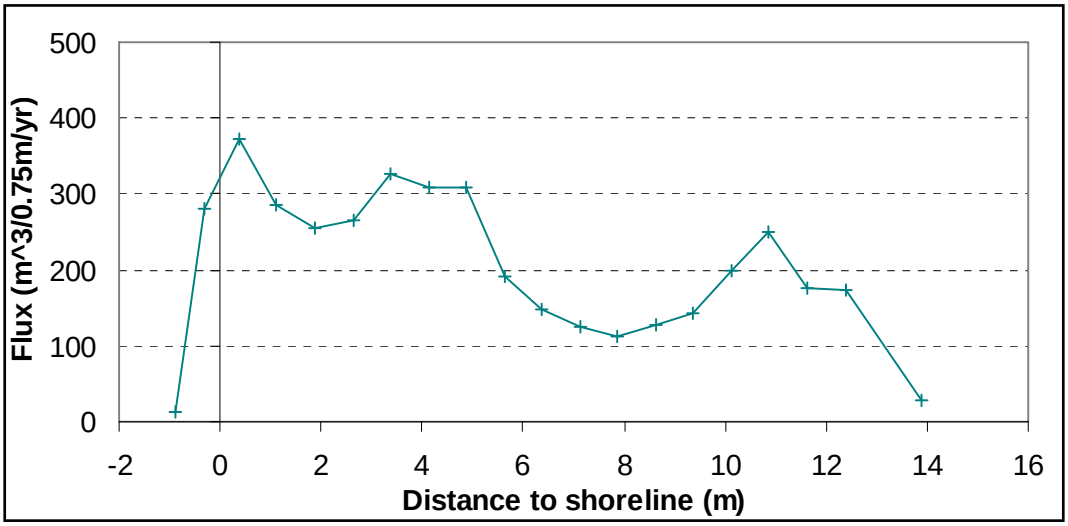


Figure 25. Cross-shore distribution of longshore sediment flux, B_C5.

3 Test 1 and Test 2 Experiments

The Test 1 and Test 2 experiments were performed to assemble data sets for testing and validation of numerical model algorithms for development of tombolos in the lee of detached nearshore breakwaters. These experiments were executed in a series of 16 runs of approximately 190 min each on a natural beach with a 4-m-long rubble-mound breakwater centrally located in the alongshore direction of the model beach and positioned 4 m offshore of the initial shoreline position (Figure 1). In all of the Test 1 runs, the estimated wave-generated longshore flux of water was recirculated from the downstream end to the upstream end of the model beach using the LSTF's external recirculation system. In the Test 2 runs, the LSTF's external recirculation system was used to recirculate double the estimated wave-generated longshore flux of water. This procedure produced an imposed longshore current varying between 5 and 10 cm/sec across the surf zone.

Breakwater construction

A 4-m-long rubble-mound breakwater was constructed in the LSTF model beach. The breakwater was positioned approximately between alongshore position Y = 22 m and Y = 26 m and at cross-shore position X = 7 m (4 m offshore of the initial shoreline position at X = 3 m). The movable bed sand beach was excavated down to the concrete floor (Figure 26) and four rows of 10 concrete blocks were laid down to form the foundation of the model breakwater (Figure 27). The area around the breakwater foundation was backfilled including the voids in the concrete blocks and filter cloth was laid over the breakwater foundation. An approximately 12-cm deep trench was dug around the breakwater foundation and the edges of the filter cloth were placed in the trench and backfilled. Two rows of 11 concrete blocks were placed on top of the filter cloth and the voids in the blocks were filled with sand (Figure 28). A third and final course of 10 concrete blocks was stacked on top of the second layer of blocks and again the voids were filled with sand (Figure 29). The concrete block breakwater core was covered with one or two layers of riprap stone to complete construction of the breakwater structure (Figures 30 and 31).

Figure 26. Excavated sand beach for breakwater construction.

Figure 27. Concrete block breakwater foundation and core.

Figure 28. Filter cloth covering foundation and second layer concrete block core.

Figure 29. Third layer concrete block breakwater core.

Figure 30. Completed breakwater structure in LSTF model beach.

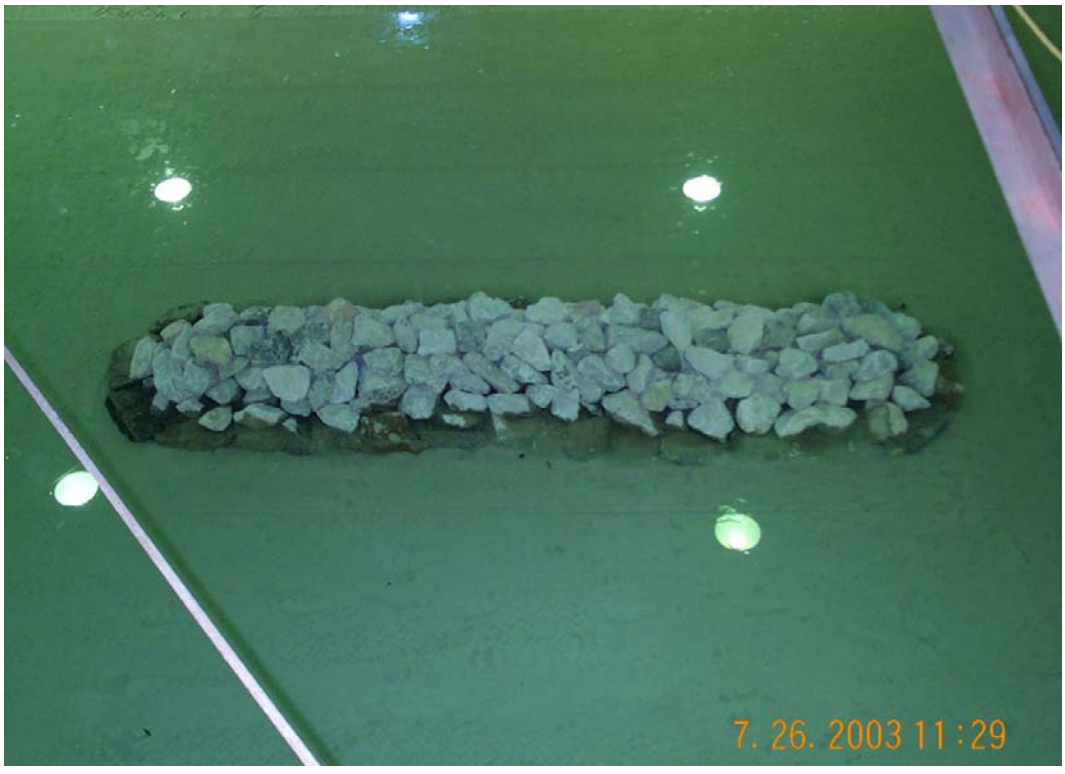


Figure 31. Breakwater structure in filled LSTF at operating water level.

T1C1

Test 1 Case 1 (T1C1) involved a 185-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at 13 cross-shore transects (alongshore positions 14, 18, 30, 34, and at 1-m intervals between alongshore position 20 and 28). The data for this run are compiled in eight files as follows:

1. T1C1pre.BM (BMAP file, pre-run survey 17 profile lines).
2. T1C1.BM (BMAP file, post-run survey 52 profile lines).
3. T1C1p.xyz (ASCII file, pre-run survey data xyz format).
4. T1C1.xyz (ASCII file, post-run survey data xyz format).
5. T1C1_current_summary.xls (Excel file, current data).
6. T1C1_wave_summary.xls (Excel file, wave data).
7. T1C1_fobs_summary.xls (Excel file, sediment concentration data).
8. T1C1_trap_summary.xls (Excel file, sediment trap data).

Figures 32 and 33 provide images of DTMs based on the pre and post-run survey data sets. The average measured cross-shore distribution of the longshore current in three regions, updrift of the structure (measurements taken at Y = 27, 28, 30, and 34), at the structure (measurements taken at Y = 22, 23, 24, 25, and 26), and downdrift of the structure (measurements taken at Y = 14, 18, 20, and 21), is plotted in Figure 34. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 35. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 36.

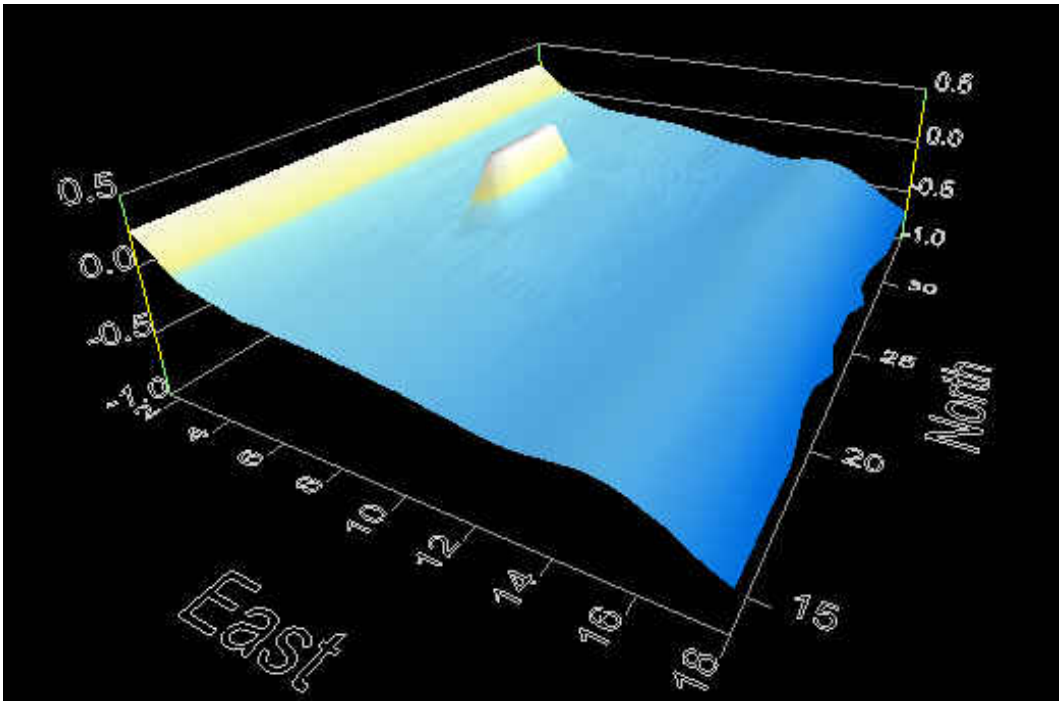


Figure 32. Initial condition model beach, T1C1.

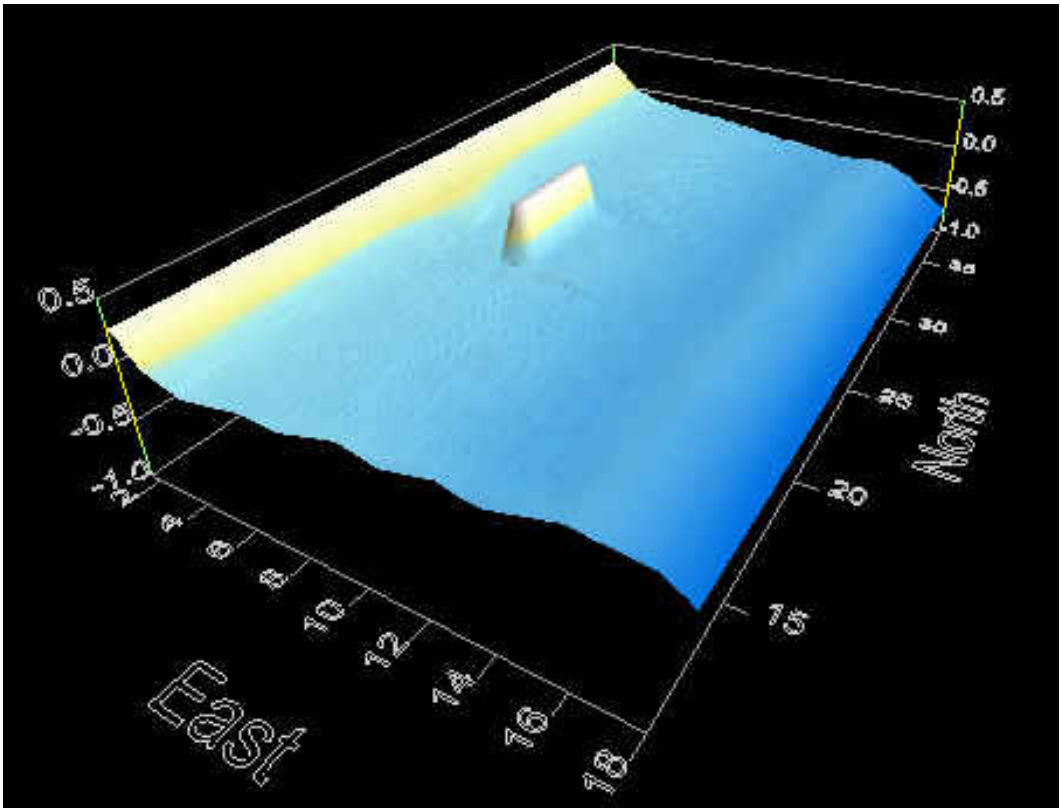


Figure 33. Post-run model beach, T1C1.

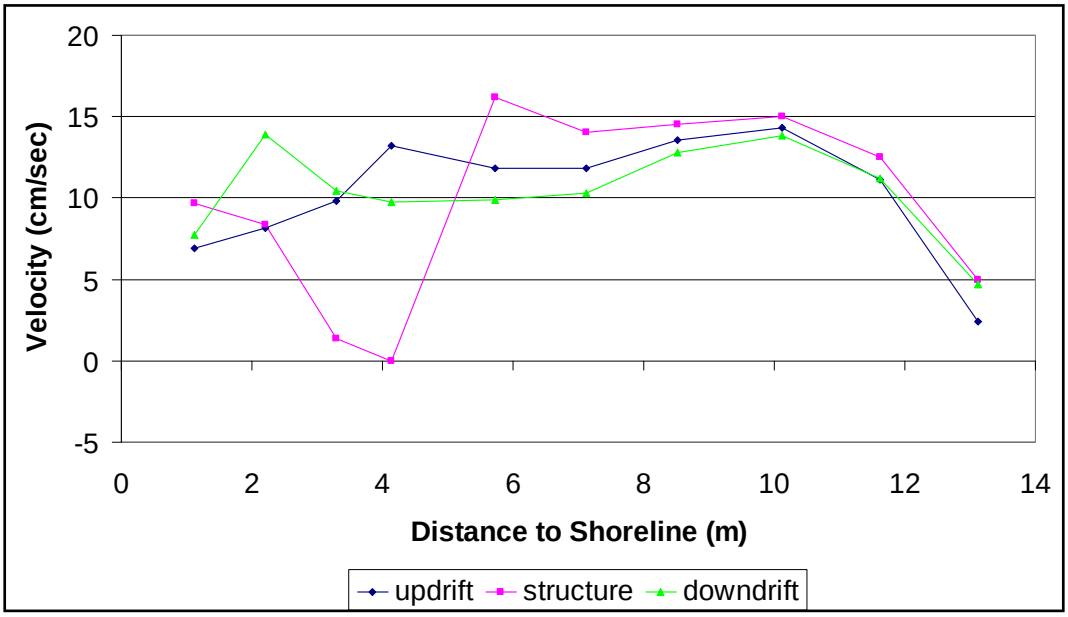


Figure 34. Cross-shore distribution of longshore current, T1C1.

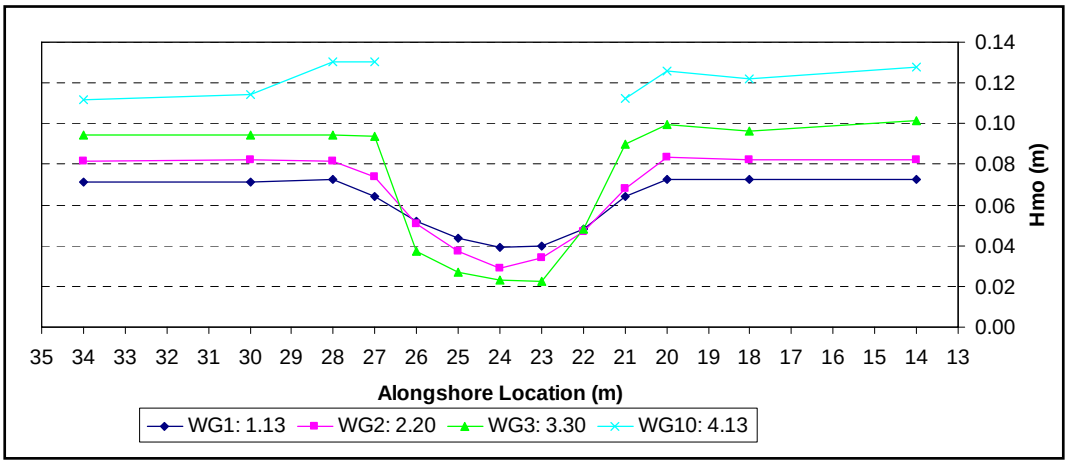


Figure 35. Distribution of wave height inshore of breakwater, T1C1.

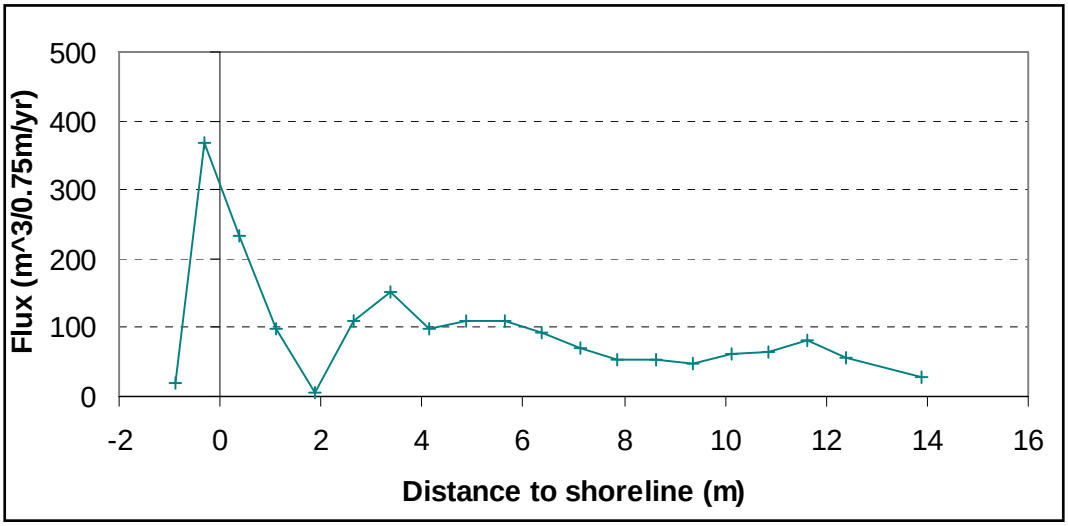


Figure 36. Cross-shore distribution of longshore sediment flux, T1C1.

T1C2

Test 1 Case 2 (T1C2) involved a 181-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T1C1. The data for this run are compiled in six files as follows:

1. T1C2.BM (BMAP file, post-run 53 profile lines).
2. T1C2.xyz (ASCII file, post-run survey data xyz format).
3. T1C2_current_summary.xls (Excel file, current data).
4. T1C2_wave_summary.xls (Excel file, wave data).
5. T1C2_fobs_summary.xls (Excel file, sediment concentration data).
6. T1C2_trap_summary.xls (Excel file, sediment trap data).

A DTM surface based on the post-run survey data is plotted in Figure 37. After 6.1 hr of waves and currents, the shoreline at apex of the sailent is 1.3 m seaward of the initial shoreline position. The toe of the sailent is in a water depth of approximately 0.1 m, and this contour has moved approximately 0.45 m toward the breakwater from this initial condition. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 38. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 39. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 40.

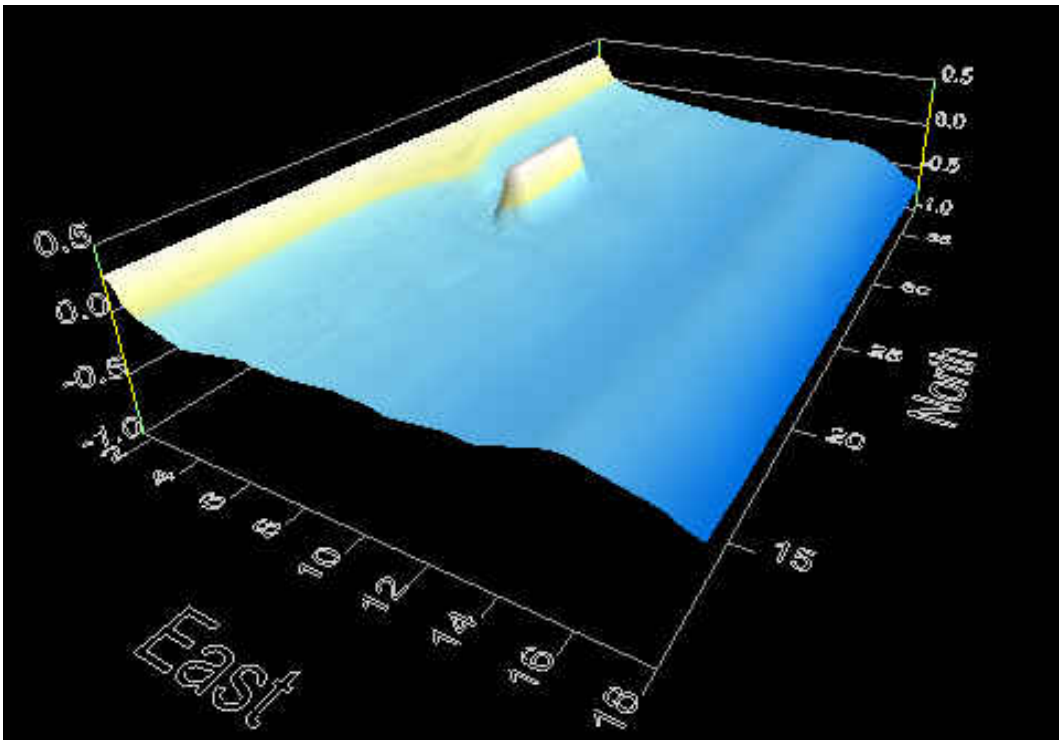


Figure 37. Post-run model beach, T1C2.

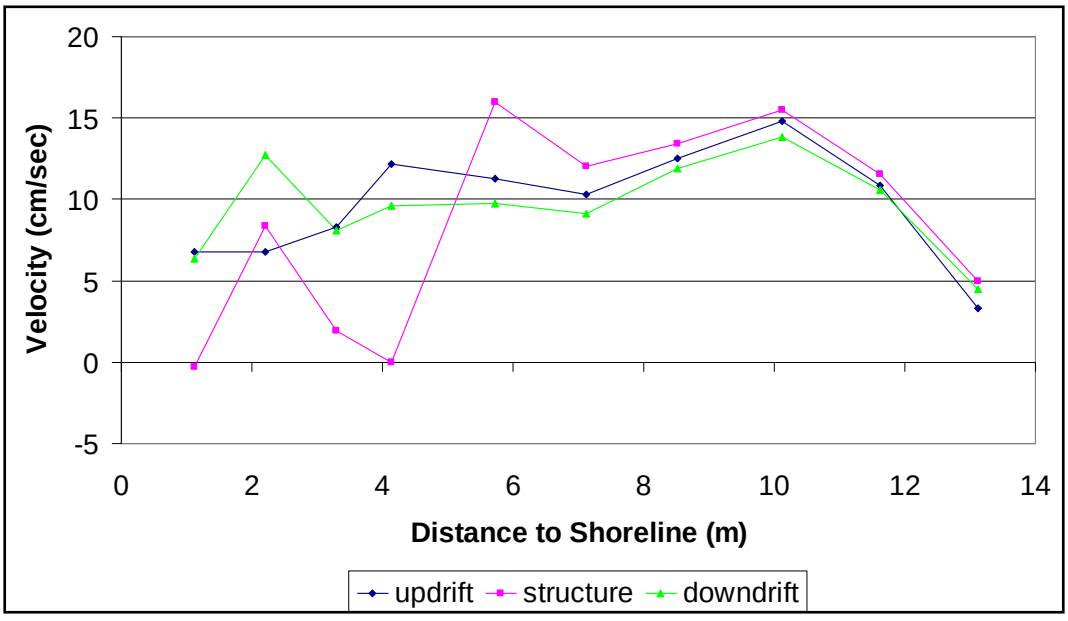


Figure 38. Cross-shore distribution of longshore current, T1C2.

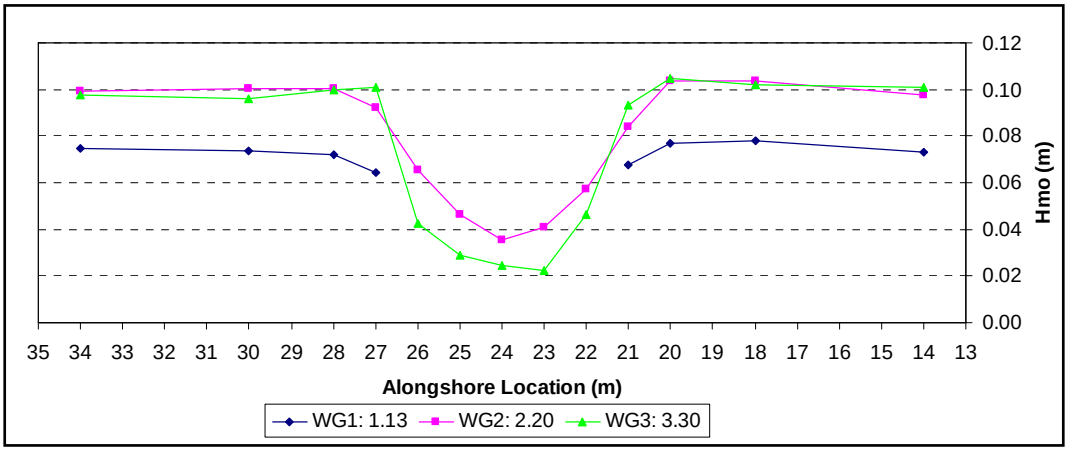


Figure 39. Distribution of wave height inshore of breakwater, T1C2.

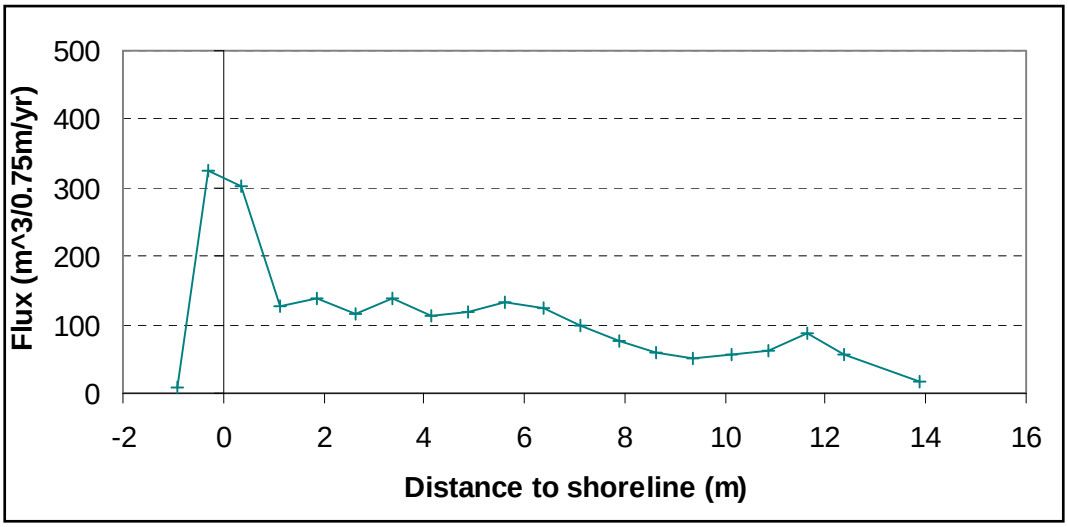


Figure 40. Cross-shore distribution of longshore sediment flux, T1C2.

T1C3

Test 1 Case 3 (T1C3) involved a 185-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T1C1. The updrift beach, from updrift end of the model beach to alongshore position Y = 30 m, was reconstructed to the equilibrium template prior to the run. The data for this run are compiled in eight files as follows:

1. T1C3pre.BM (BMAP file, pre-run survey 10 profile lines).
2. T1C3.BM (BMAP file, post-run survey 53 profile lines).
3. T1C3p.xyz (ASCII file, pre-run survey data xyz format).
4. T1C3.xyz (ASCII file, post-run survey data xyz format).
5. T1C3_current_summary.xls (Excel file, current data).

6. T1C3_wave_summary.xls (Excel file, wave data).
7. T1C3_fobs_summary.xls (Excel file, sediment concentration data).
8. T1C3_trap_summary.xls (Excel file, sediment trap data).

Figures 41 and 42 provide images of DTM surfaces based on the pre- and post-run survey data sets. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 43. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 44. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 45.

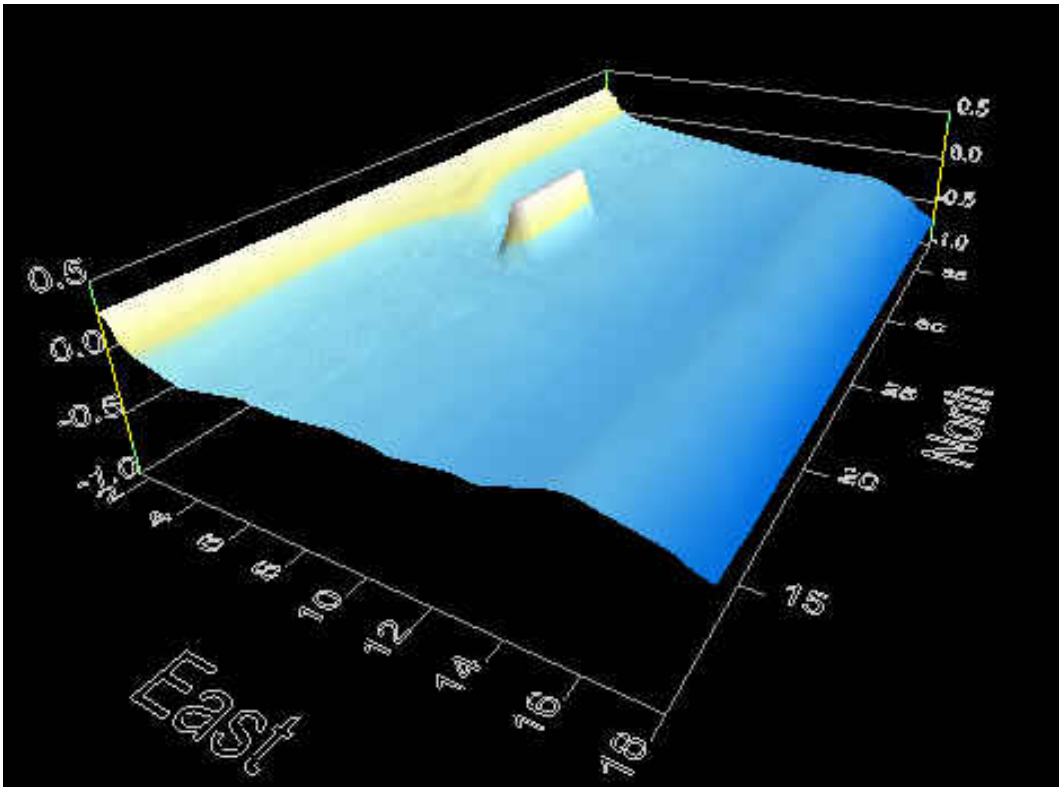


Figure 41. Initial condition model beach, T1C3.

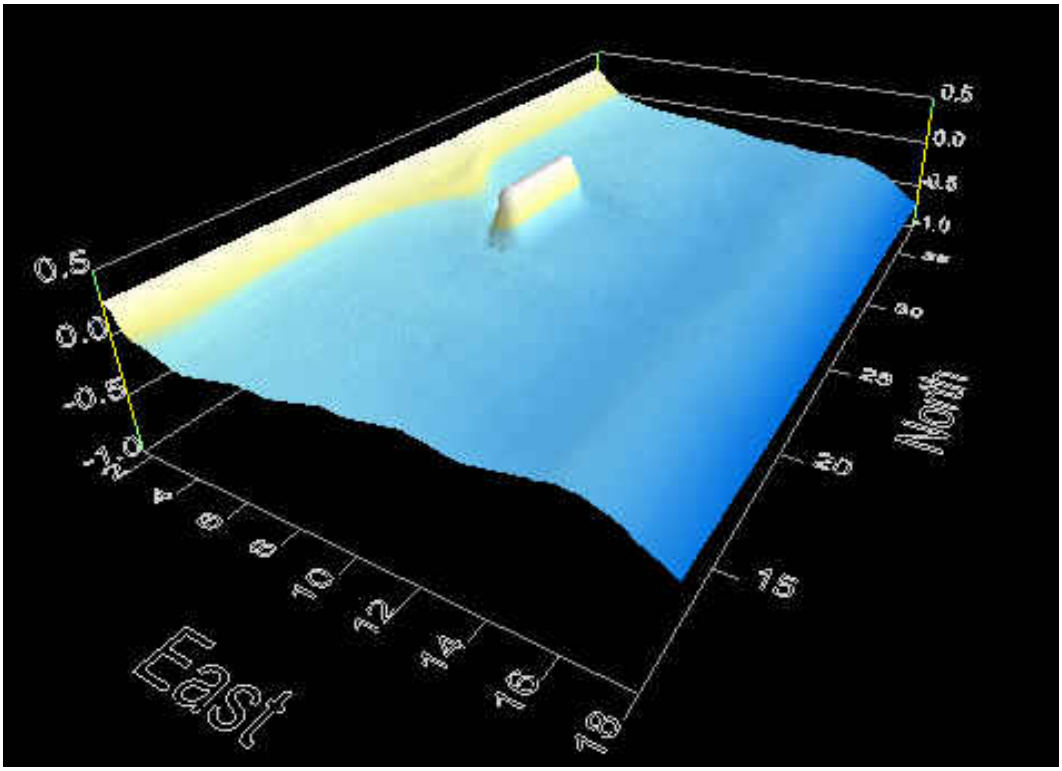


Figure 42. Post-run model beach, T1C3.

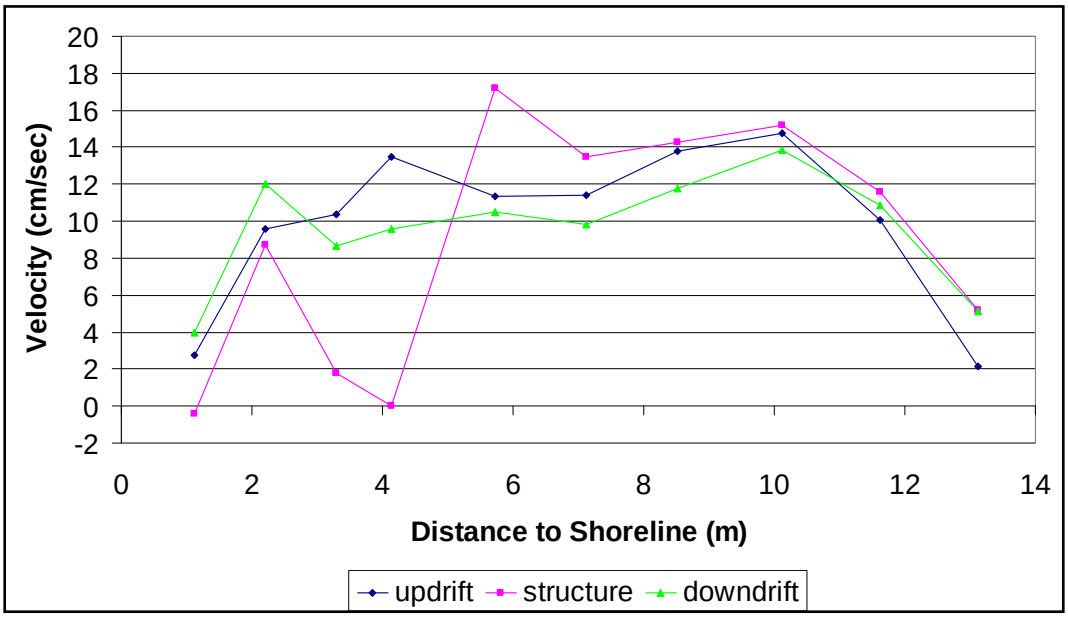


Figure 43. Cross-shore distribution of longshore current, T1C3.

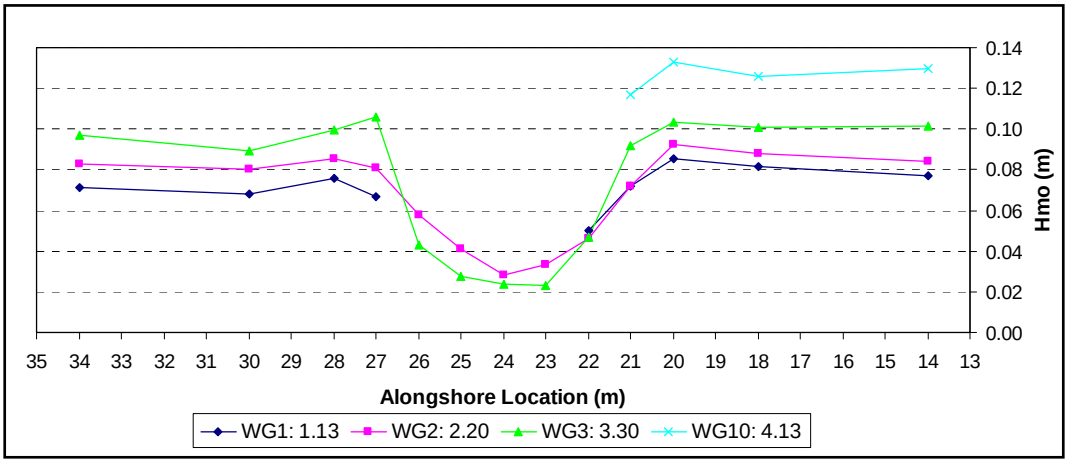


Figure 44. Distribution of wave heights inshore of breakwater, T1C3.

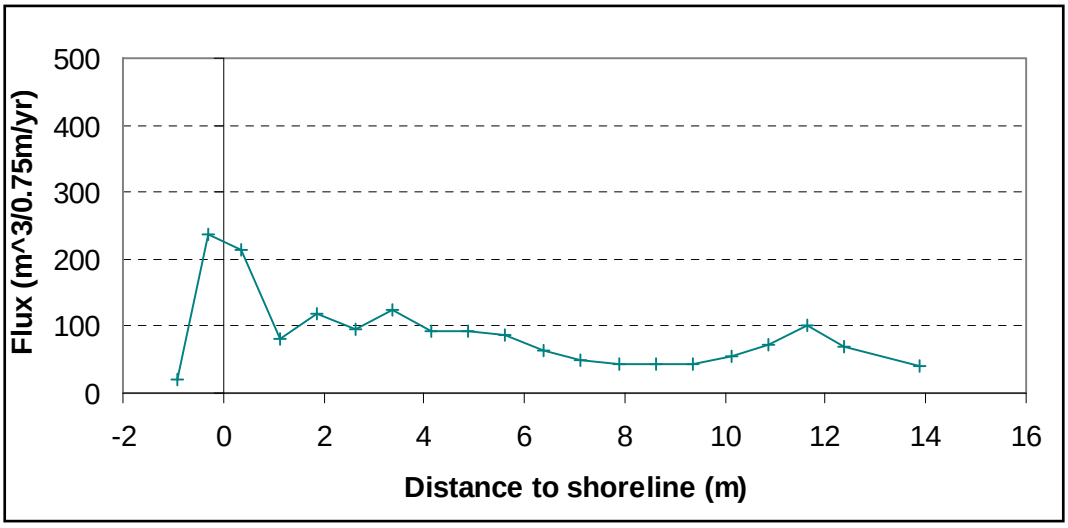


Figure 45. Cross-shore distribution of longshore sediment flux, T1C3.

T1C4

Test 1 Case 4 (T1C4) involved a 192-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T1C1. The data for this run are compiled in six files as follows:

1. T1C4.BM (BMAP file, post-run survey 53 profile lines).
2. T1C4.xyz (ASCII file, post-run survey data xyz format).
3. T1C4_current_summary.xls (Excel file, current data).
4. T1C4_wave_summary.xls (Excel file, wave data).
5. T1C4_fobs_summary.xls (Excel file, sediment concentration data).
6. T1C4_trap_summary.xls (Excel file, sediment trap data).

Figure 46 provides a DTM surface based on the post-run survey data. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 47. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 48. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 49.

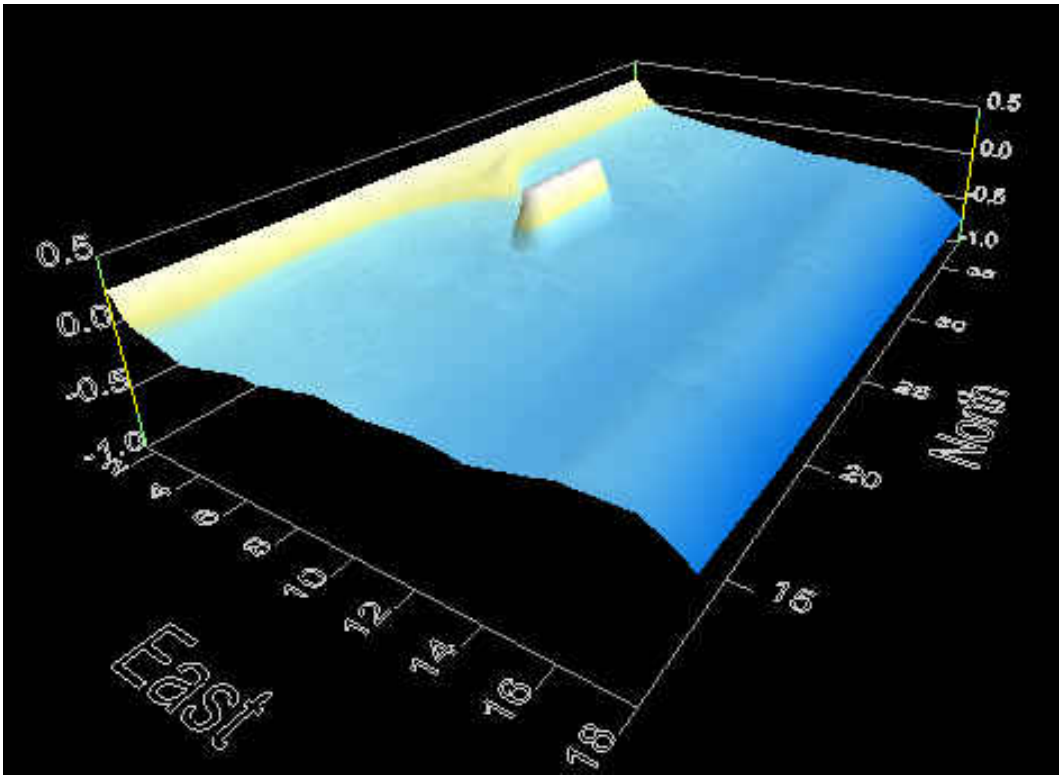


Figure 46. Post-run model beach, T1C4.

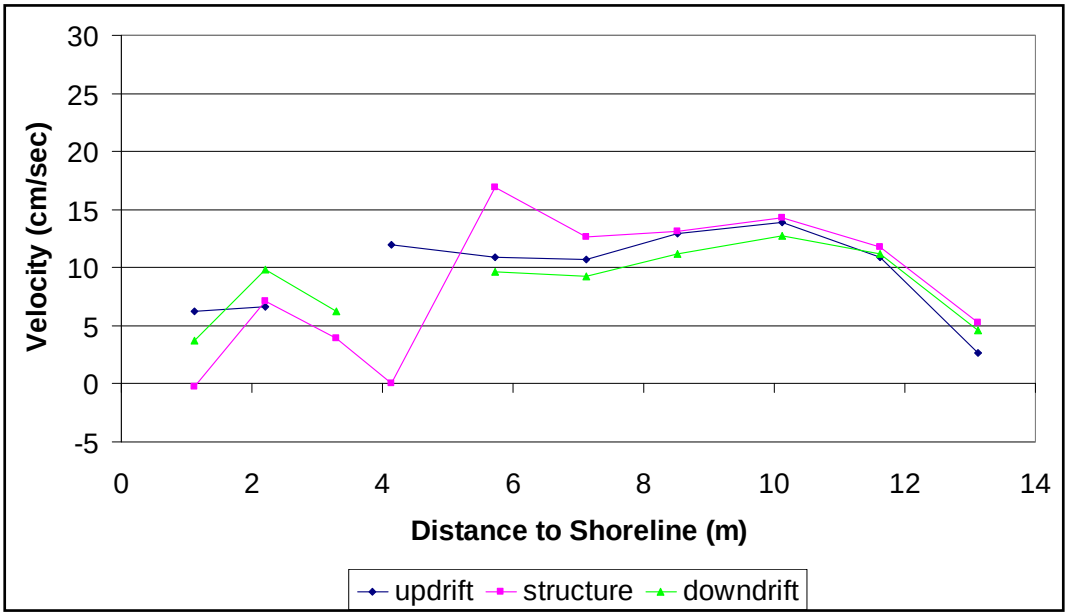


Figure 47. Cross-shore distribution of longshore current, T1C4.

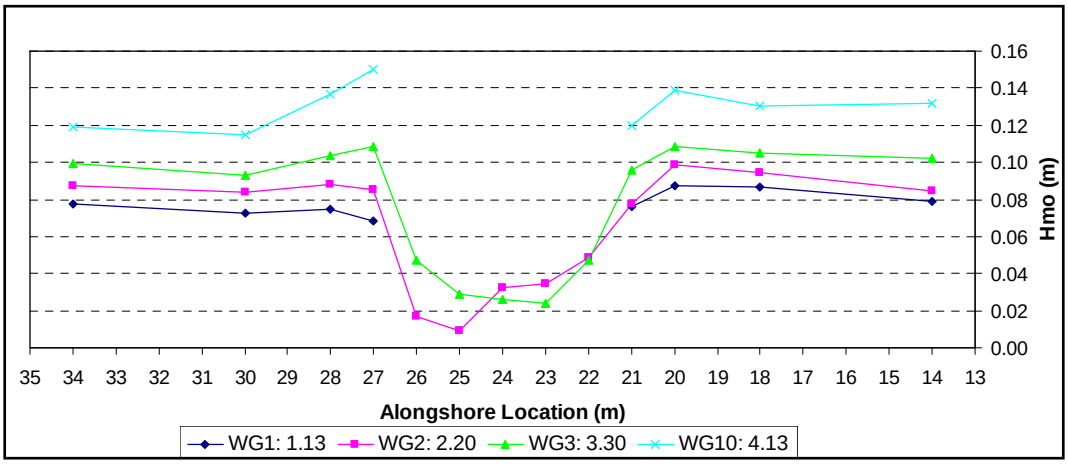


Figure 48. Distribution of wave height inshore of breakwater, T1C4.

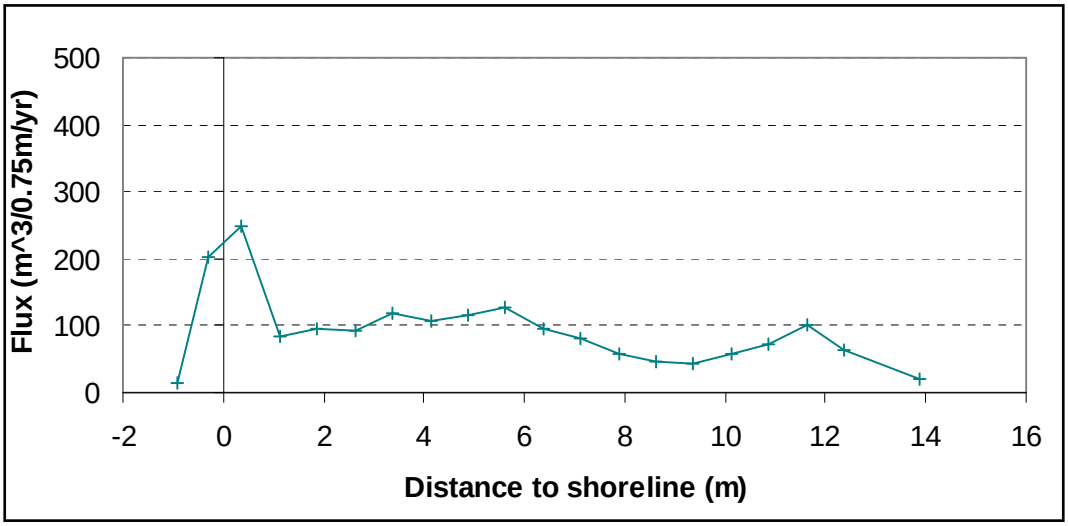


Figure 49. Cross-shore distribution of longshore sediment flux, T1C4.

T1C5

Test 1 Case 5 (T1C5) involved a 176-min run with waves and currents. A 22-min aborted run with waves and currents occurred prior to the full T1C5 run. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T1C1. The data for this run are compiled in six files as follows:

1. T1C5.BM (BMAP file, post-run survey 53 profile lines).
2. T1C5.xyz (ASCII file, post-run survey data xyz format).
3. T1C5_current_summary.xls (Excel file, current data).
4. T1C5_wave_summary.xls (Excel file, wave data).
5. T1C5_fobs_summary.xls (Excel file, sediment concentration data).
6. T1C5_trap_summary.xls (Excel file, sediment trap data).

Figure 50 provides a DTM surface based on the post-run survey data. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 51. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 52. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 53.

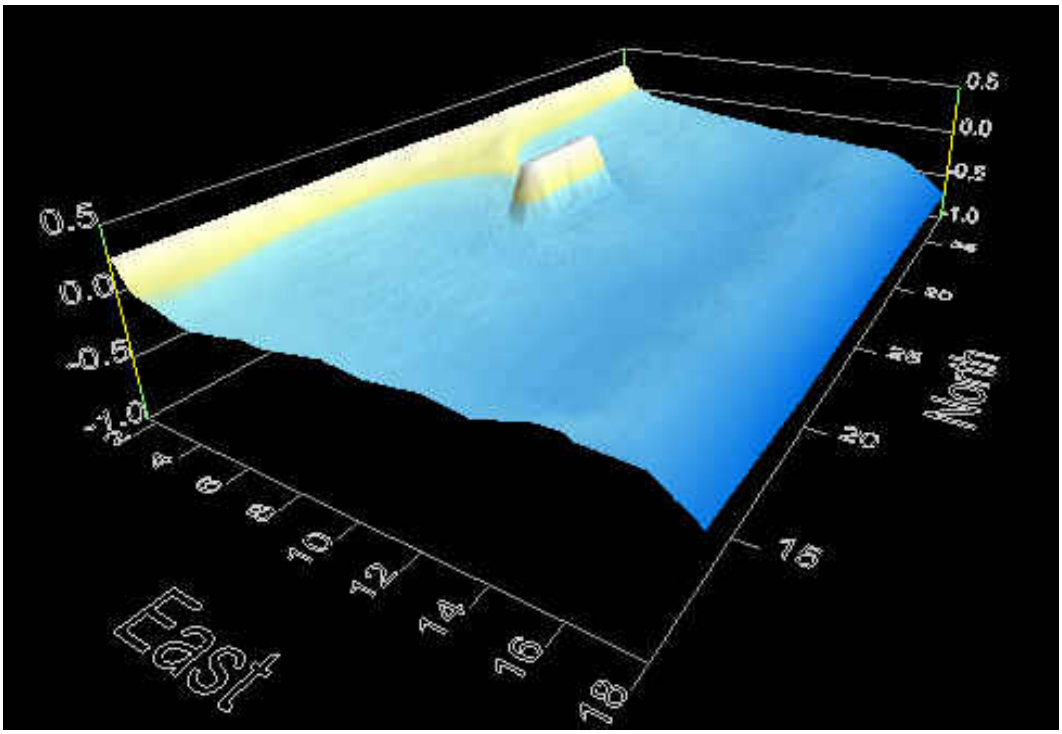


Figure 50. Post-run model beach, T1C5.

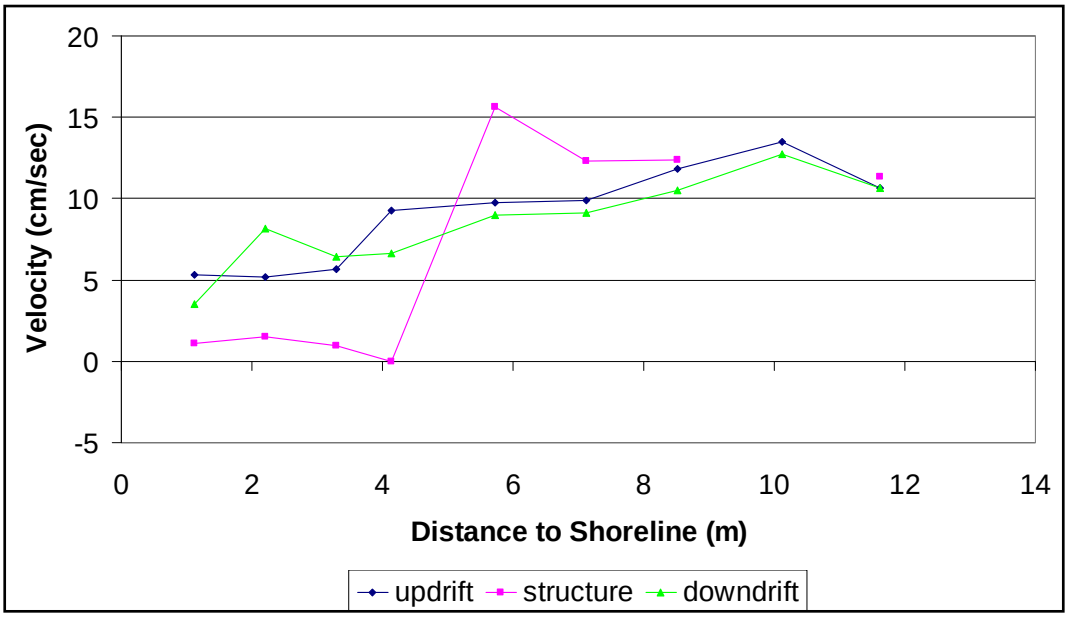


Figure 51. Cross-shore distribution of longshore current, T1C5.

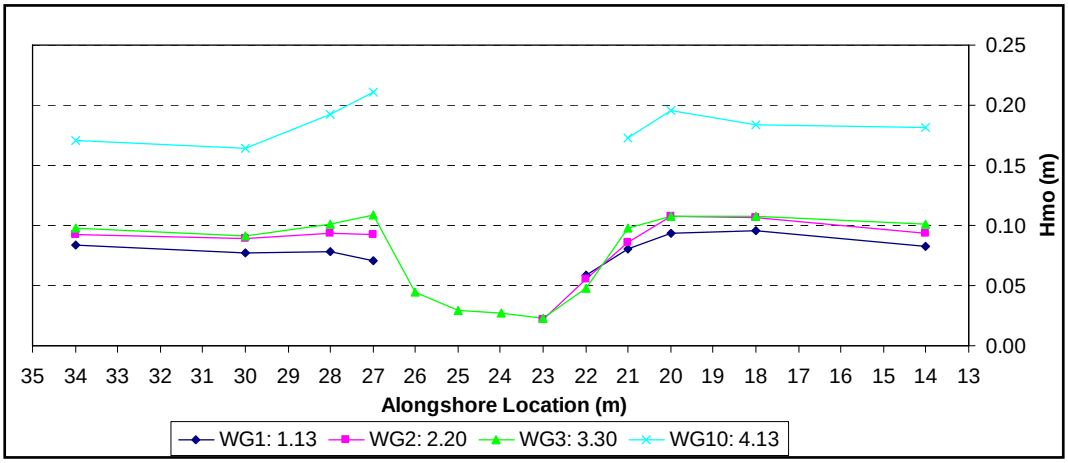


Figure 52. Distribution of wave height inshore of breakwater, T1C5.

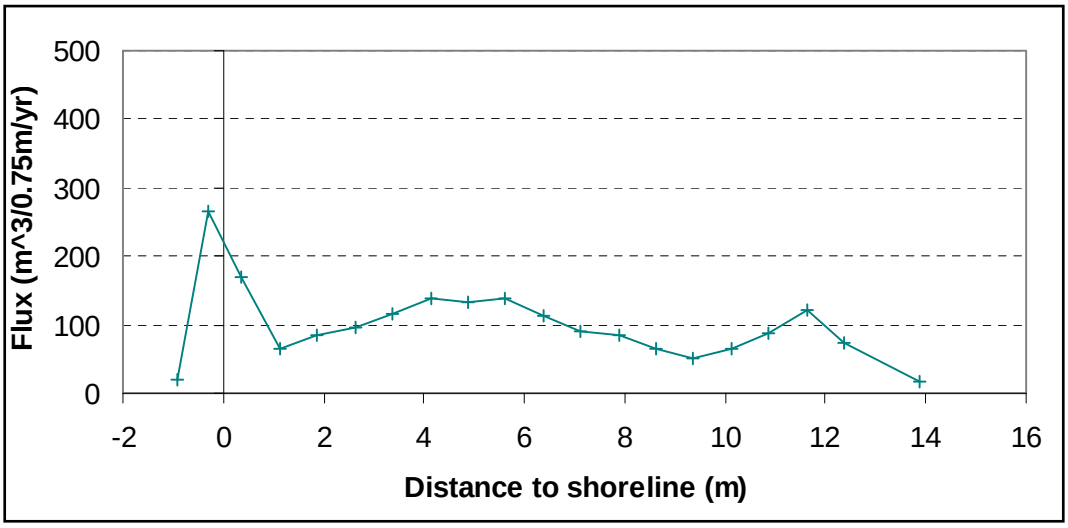


Figure 53. Cross-shore distribution of longshore sediment flux, T1C5.

T1C6

Test 1 Case 6 (T1C6) involved a 189-min run with waves and currents. After run T1C5, the updrift beach, from the updrift end of the model beach to alongshore position Y = 30 m, was reconstructed to the equilibrium template prior to the run. A small nearshore berm feature was constructed updrift of the breakwater and sailent as illustrated in Figures 54 and 55. The volume of sand placed in the nearshore berm was 0.123 cu m. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T1C1. The data for this run are compiled in eight files as follows:

1. T1C6pre.BM (BMAP file, pre-run survey 31 profile lines).

2. T1C6.BM (BMAP file, post-run survey 68 profile lines).
3. T1C6p.xyz (ASCII file, pre-run survey data xyz format).
4. T1C6.xyz (ASCII file, post-run survey data xyz format).
5. T1C6_current_summary.xls (Excel file, current data).
6. T1C6_wave_summary.xls (Excel file, wave data).
7. T1C6_fobs_summary.xls (Excel file, sediment concentration data).
8. T1C6_trap_summary.xls (Excel file, sediment trap data).

Figures 56 and 57 provide images of DTM surfaces based on the pre- and post-run survey data. The nearshore berm feature was dispersed by the wave action during this run as evidenced by the pre- and post-run contours shown in Figures 58 and 59. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 60. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 61. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 62.

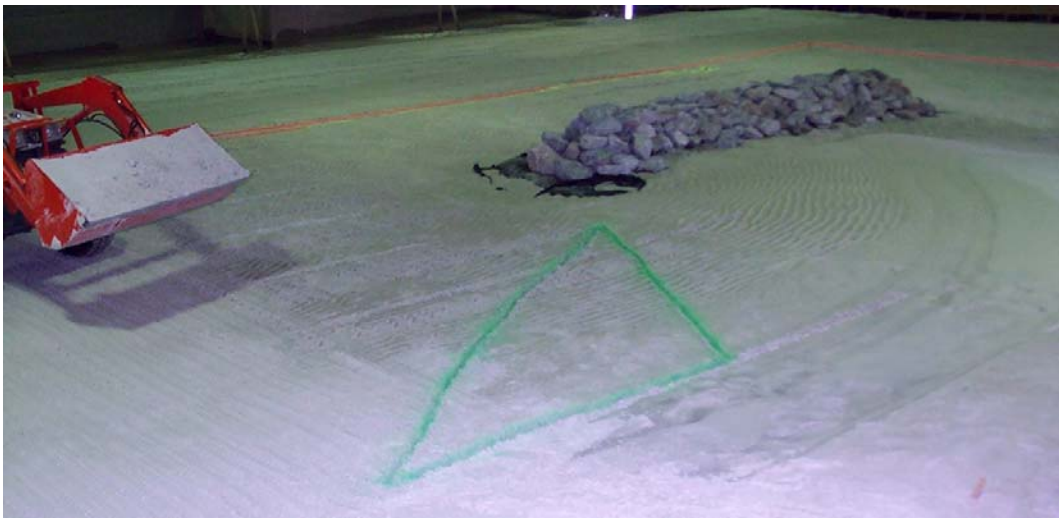


Figure 54. Lay-out location for nearshore berm feature.

Figure 55. Nearshore berm feature constructed updrift of breakwater and sailent.

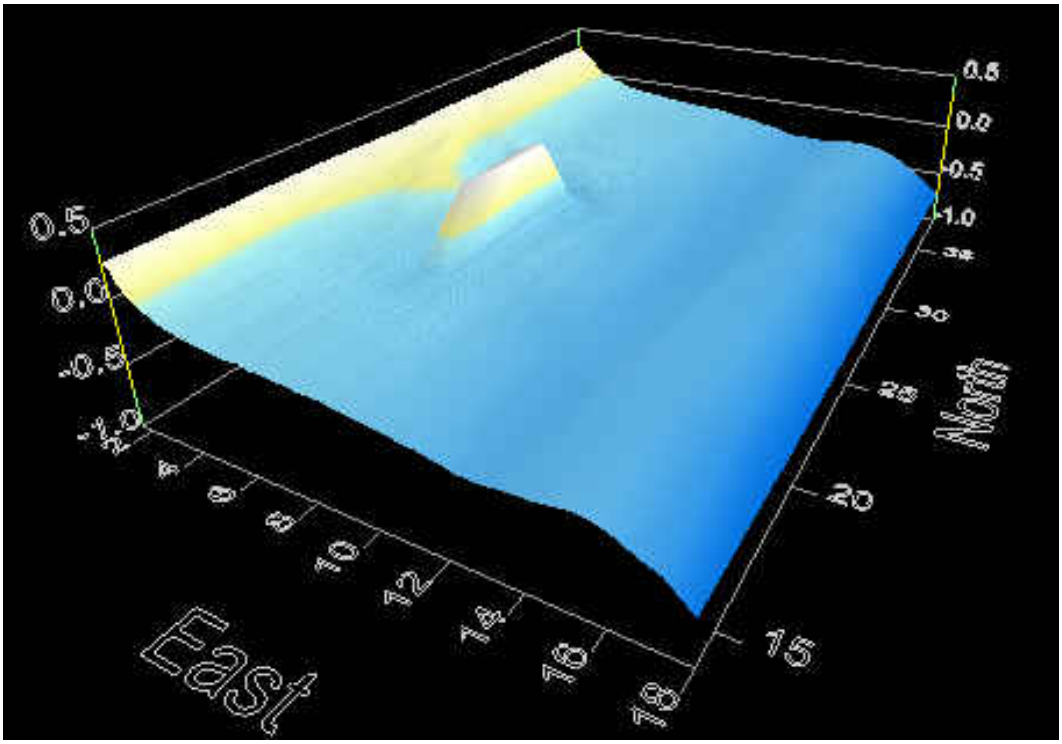


Figure 56. Initial condition model beach, T1C6.

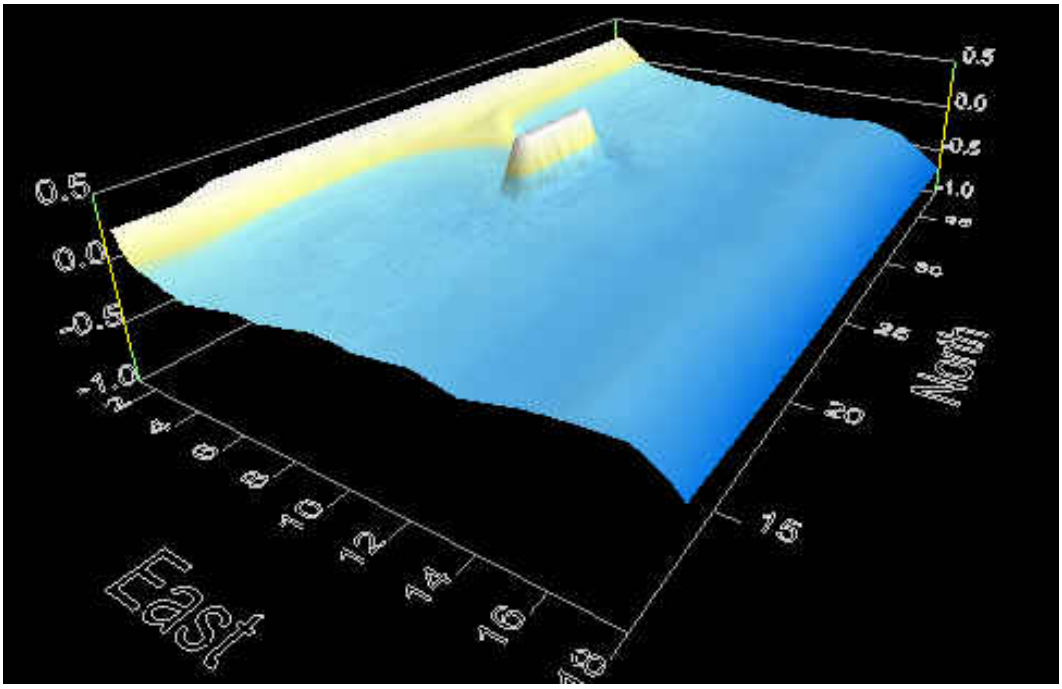


Figure 57. Post-run model beach, T1C6.

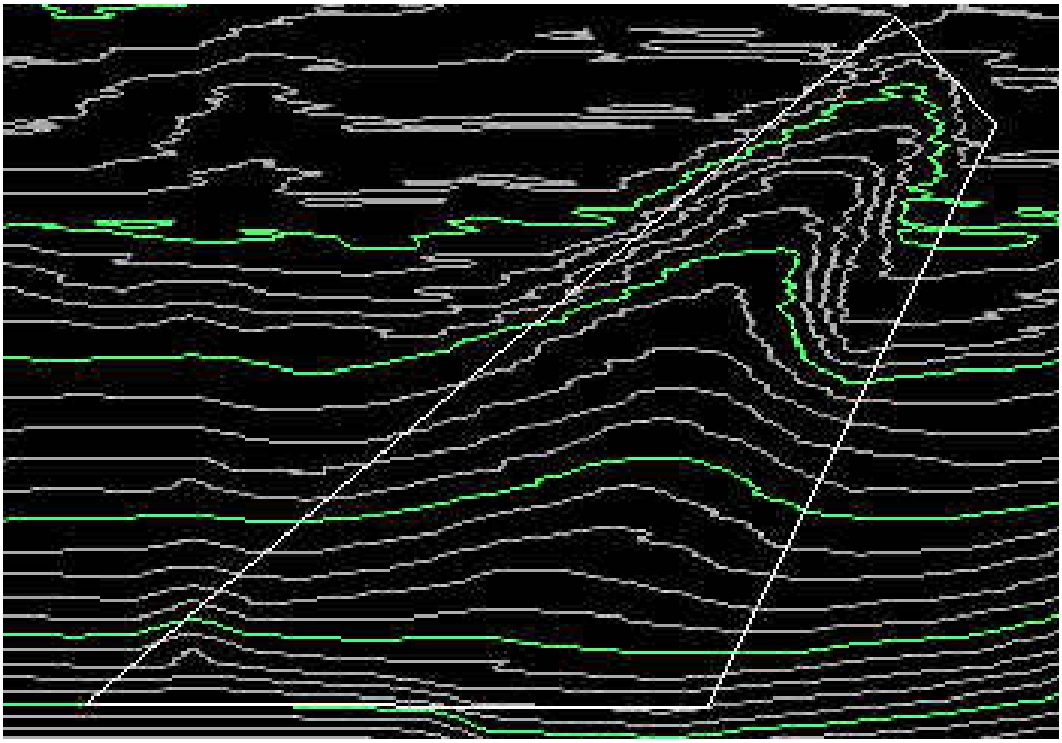


Figure 58. Nearshore berm contours pre-run, T1C6.

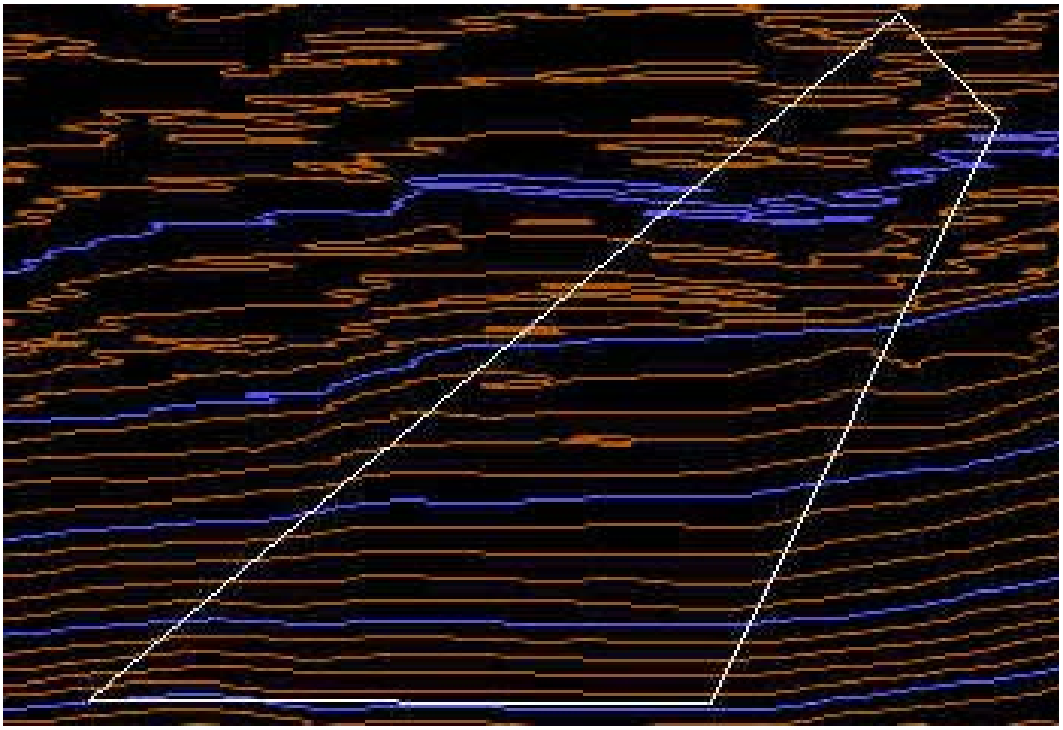


Figure 59. Nearshore berm contours post-run, T1C6.

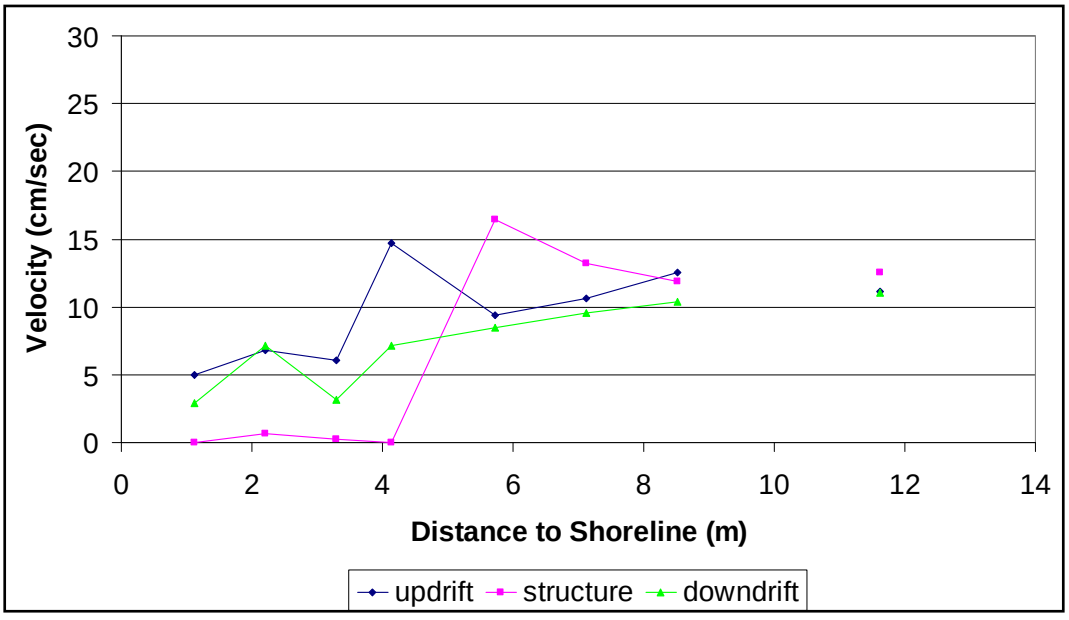


Figure 60. Cross-shore distribution of longshore currents, T1C6.

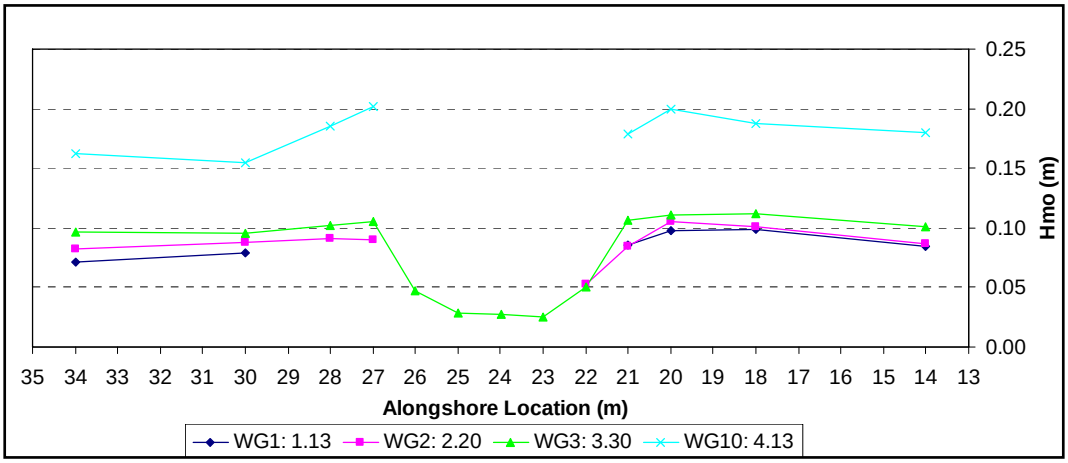


Figure 61. Distribution of wave height inshore of breakwater, T1C6.

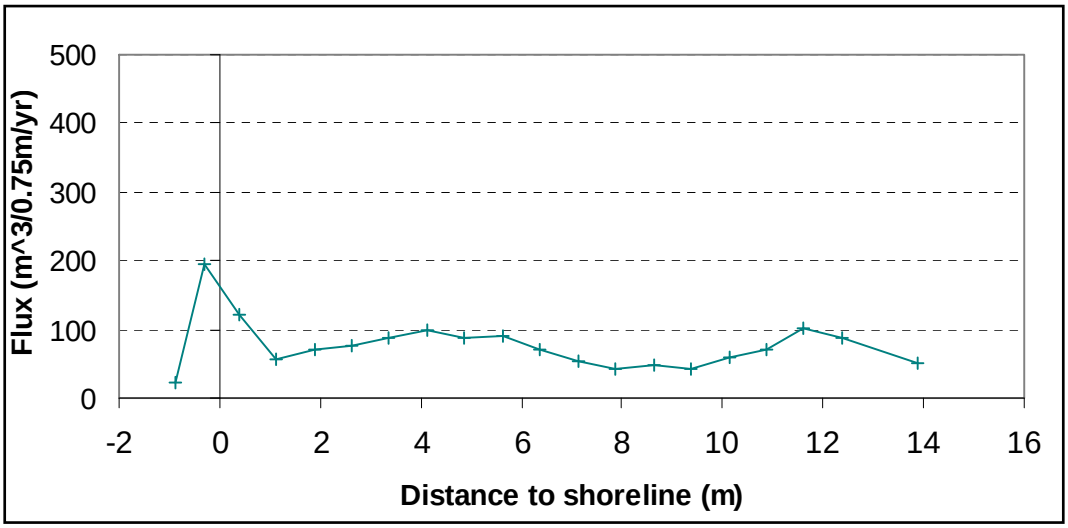


Figure 62. Cross-shore distribution of longshore sediment flux, T1C6.

T1C7

Test 1 Case 7 (T1C7) involved a 191 min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T1C1. The data for this run are compiled in six files as follows:

1. T1C7.BM (BMAP file, post-run survey 68 profile lines).
2. T1C7.xyz (ASCII file, post-run survey data xyz format).
3. T1C7_current_summary.xls (Excel file, current data).
4. T1C7_wave_summary.xls (Excel file, wave data).
5. T1C7_fobs_summary.xls (Excel file, sediment concentration data).
6. T1C7_trap_summary.xls (Excel file, sediment trap data).

Figure 63 provides a DTM surface based on the post-run survey data. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 64. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 65. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 66.

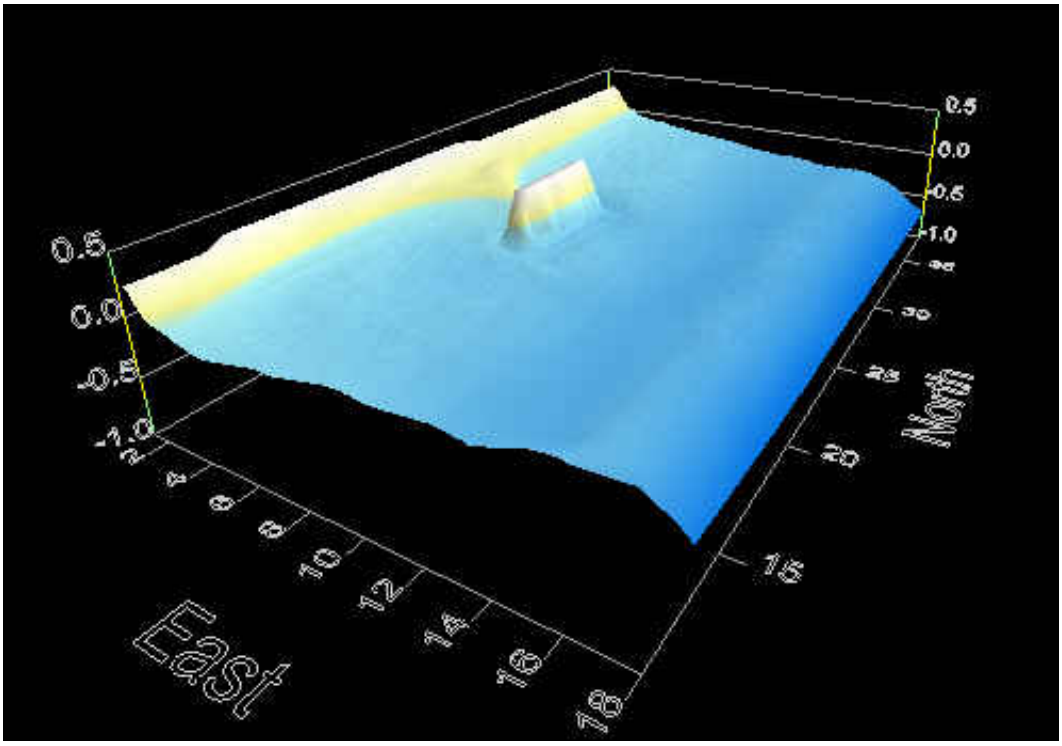


Figure 63. Post-run model beach, T1C7.

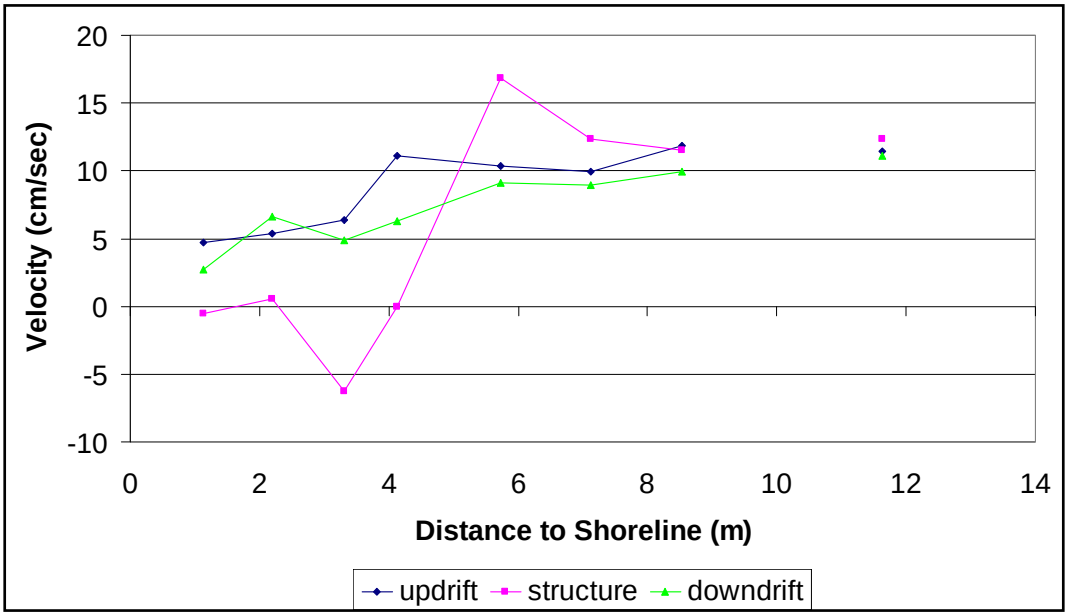


Figure 64. Cross-shore distribution of longshore current, T1C7.

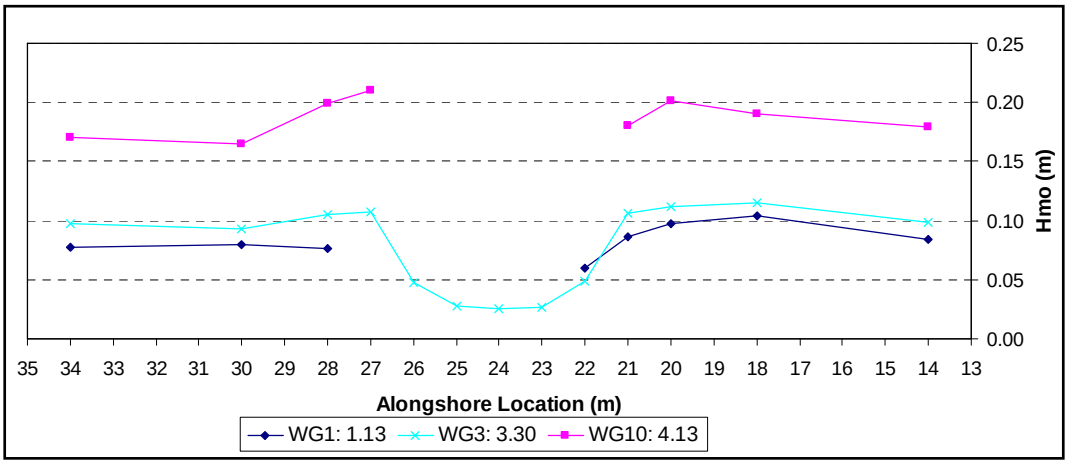


Figure 65. Distribution of wave height inshore of breakwater, T1C7.

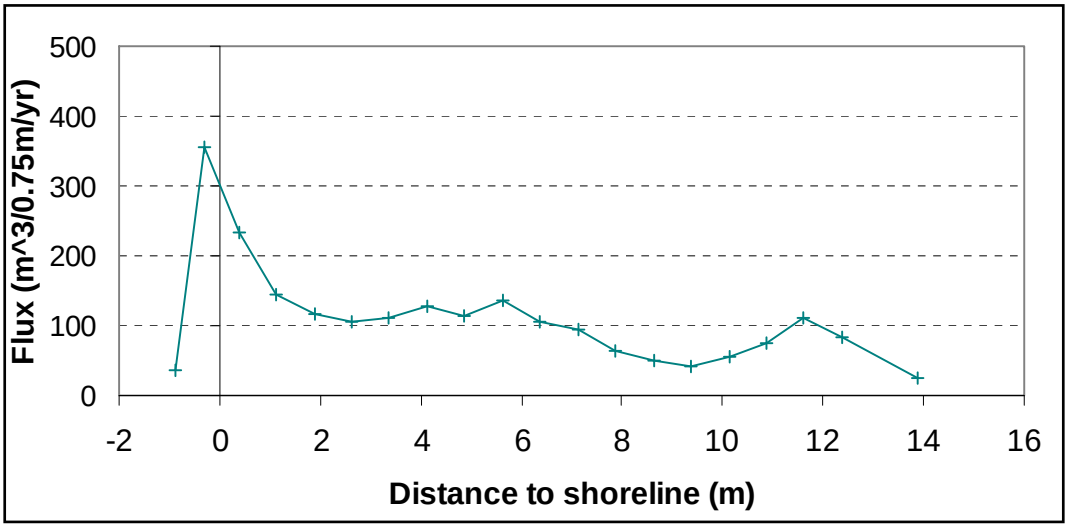


Figure 66. Cross-shore distribution of longshore sediment flux, T1C7.

T1C8

Test 1 Case 8 (T1C8) involved a 184-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T1C1. The data for this run are compiled in six files as follows:

1. T1C8.BM (BMAP file, post-run 58 profile lines).
2. T1C8.xyz (ASCII file, post-run survey data xyz format).
3. T1C8_current_summary.xls (Excel file, current data).
4. T1C8_wave_summary.xls (Excel file, wave data).
5. T1C8_fobs_summary.xls (Excel file, sediment concentration data).
6. T1C8_trap_summary.xls (Excel file, sediment trap data).

Figure 67 provides a DTM surface based on the post-run survey data. A full tombolo was formed at the end of this run as seen from the contours in Figure 68 (the gray contour is the zero elevation contour). The cross-shore distribution of the longshore current is plotted in Figure 69. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 70. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 71.

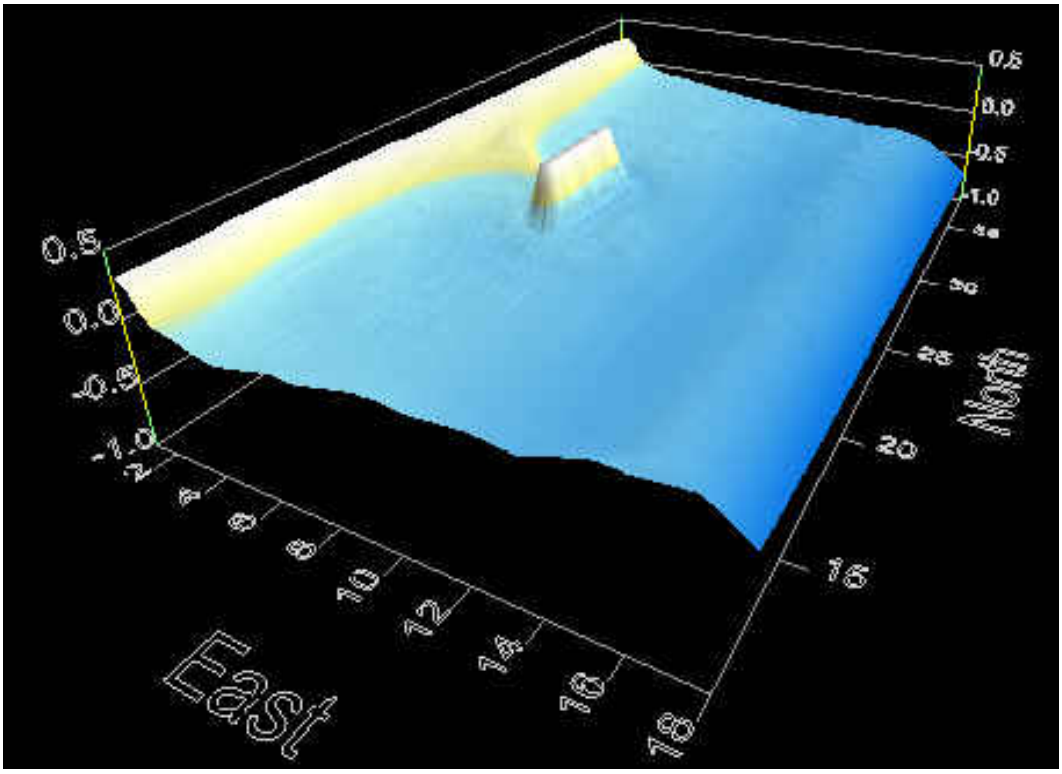


Figure 67. Post-run model beach, T1C8.

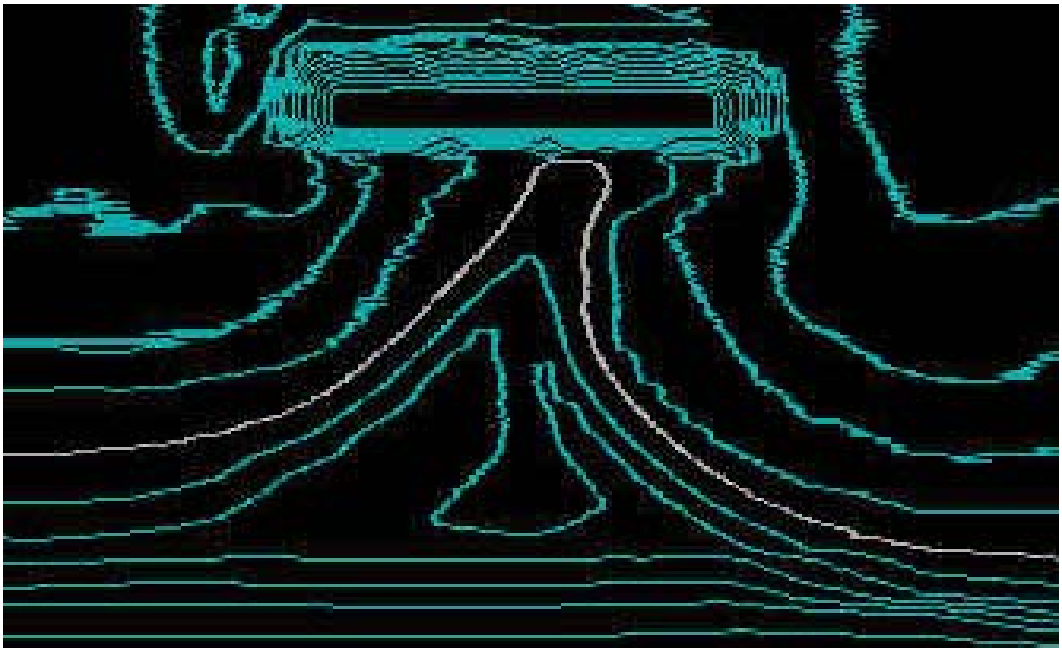


Figure 68. Post-run model beach contours, T1C8.

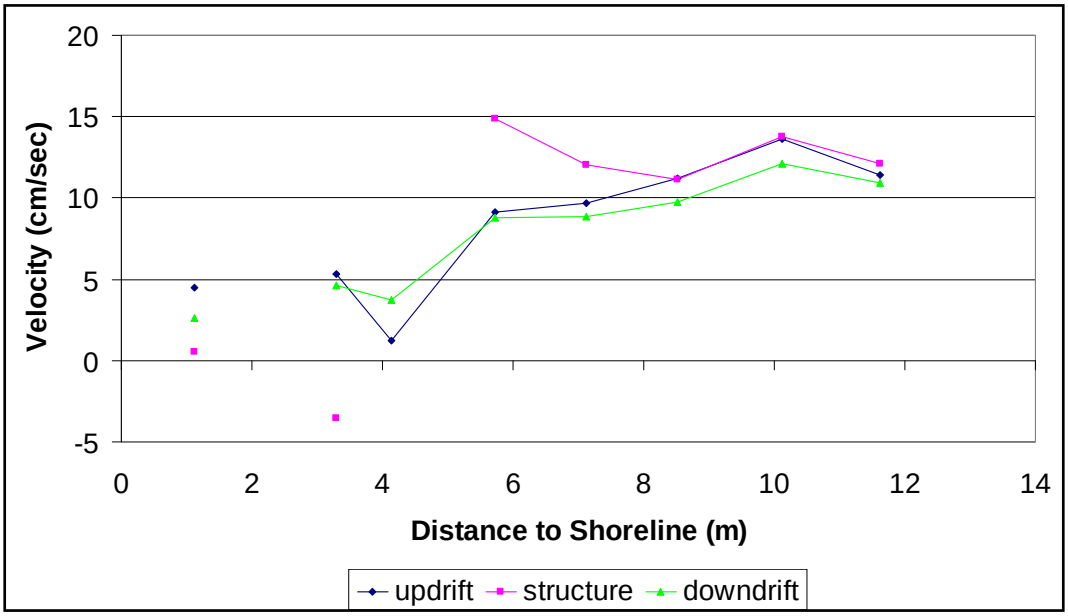


Figure 69. Cross-shore distribution of longshore current, T1C8.

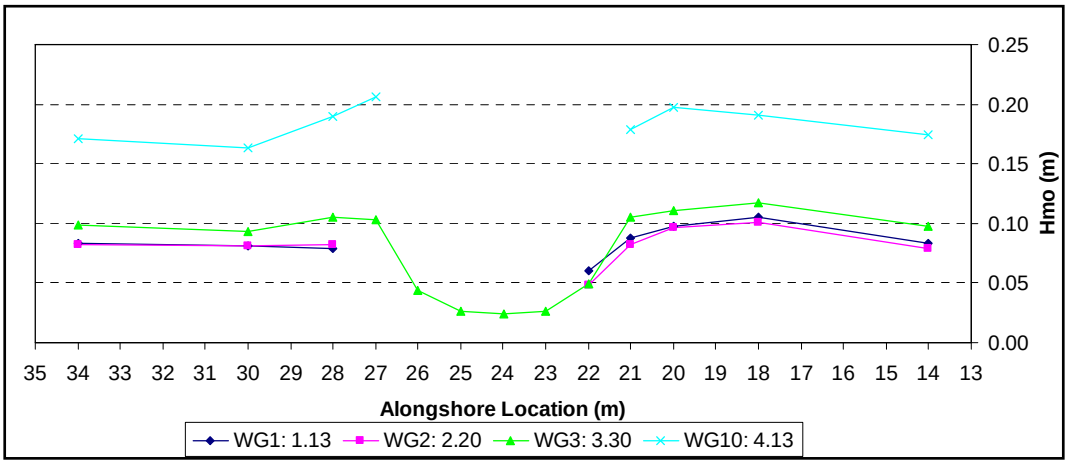


Figure 70. Distribution of wave height inshore of breakwater, T1C8.

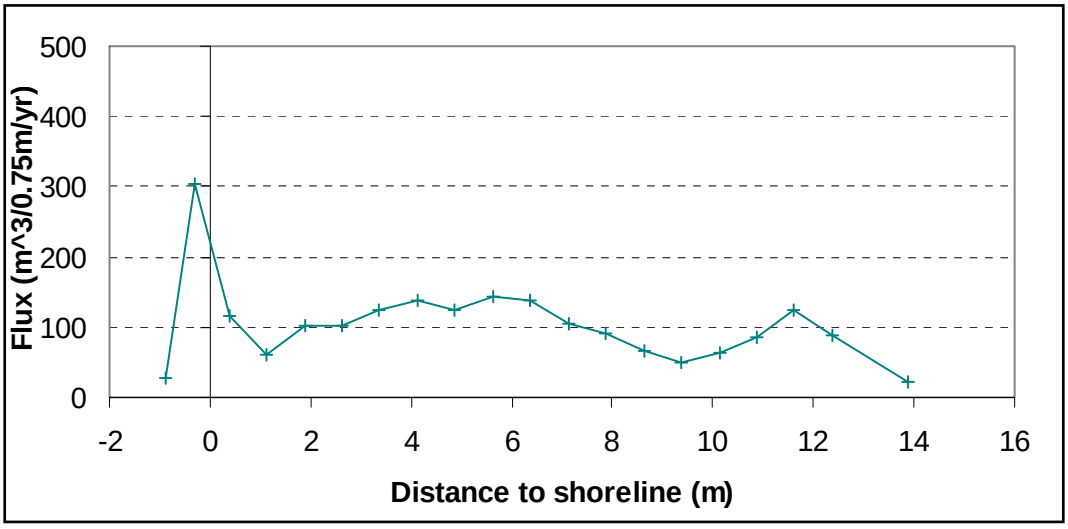


Figure 71. Cross-shore distribution of longshore sediment flux, T1C8.

Test 2 Experiments

In the Test 2 experiments (T2C1 through T2C8), an external longshore current was imposed across the model beach by recirculating twice the longshore wave-generated flux of water (twice the volume of water recirculated in the Test 1 experiments). Due to the imposed external longshore sand transport rates were larger and sediment volume collected in the sediment traps was greater than in the Test 1 series of runs. In this test series, the sediment traps were dredged and the updrift beach was rebuilt to the equilibrium template after runs T2C2 (t = 6 hr), T2C4 (t = 12 hr), and T2C6 (t = 18 hr). After run T2C8, the salient had advanced seaward to within about 10 cm of the breakwater.

T2C1

Test 2 Case 1 (T2C1) involved a 185-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at 13 cross-shore transects (alongshore positions 14, 18, 30, 34, and at 1-m intervals between alongshore position 20 and 28). The data for this run are compiled in eight files as follows:

1. T2C1pre.BM (BMAP file, pre-run survey 25 profile lines).
2. T2C1.BM (BMAP file, post-run survey 53 profile lines).
3. T2C1p.xyz (ASCII file, pre-run survey data xyz format).
4. T2C1.xyz (ASCII file, post-run survey data xyz format).
5. T2C1_current_summary.xls (Excel file, current data).
6. T2C1_wave_summary.xls (Excel file, wave data).

7. T2C1_fobs_summary.xls (Excel file, sediment concentration data).
8. T2C1_trap_summary.xls (Excel file, sediment trap data).

Figures 72 and 73 provide images of DTMs based on the pre- and post-run survey data sets. The average measured cross-shore distribution of the longshore current in three regions, updrift of the structure (measurements taken at Y = 27, 28, 30, and 34), at the structure (measurements taken at Y = 22, 23, 24, 25, and 26), and downdrift of the structure (measurements taken at Y = 14, 18, 20, and 21) is plotted in Figure 74. Also plotted in Figure 74 is the cross-shore distribution of the average imposed external longshore current, which was obtained by subtracting the T1C1 current velocities from the T2C1 current velocities. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 75. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 76.

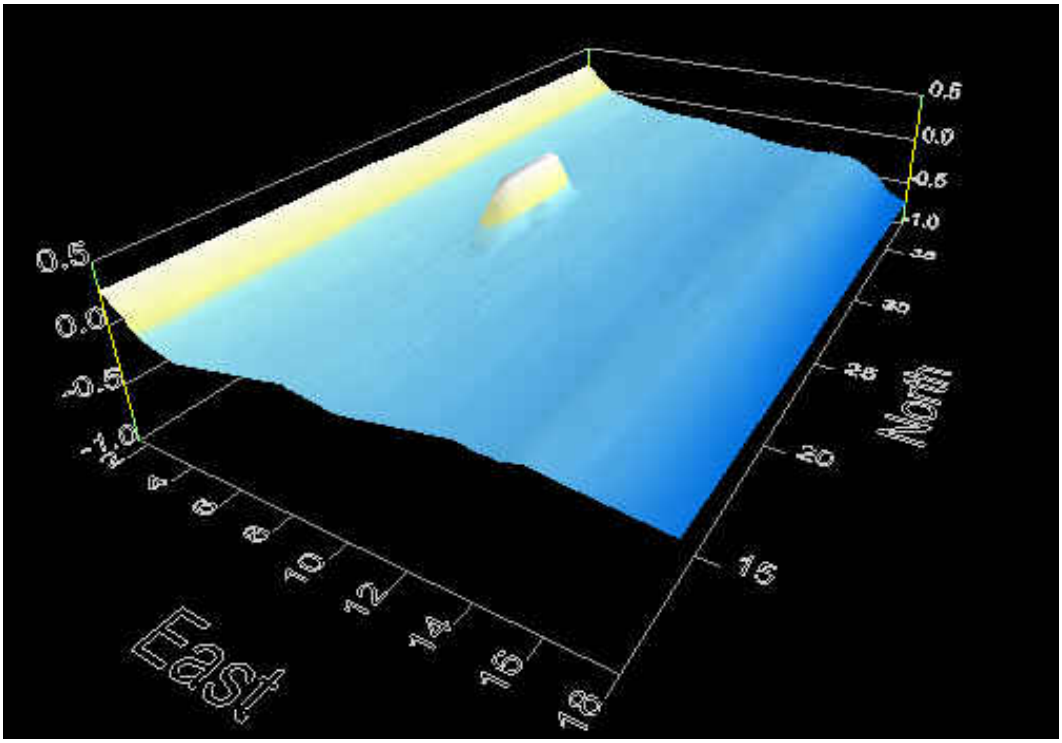


Figure 72. Initial condition model beach, T2C1.

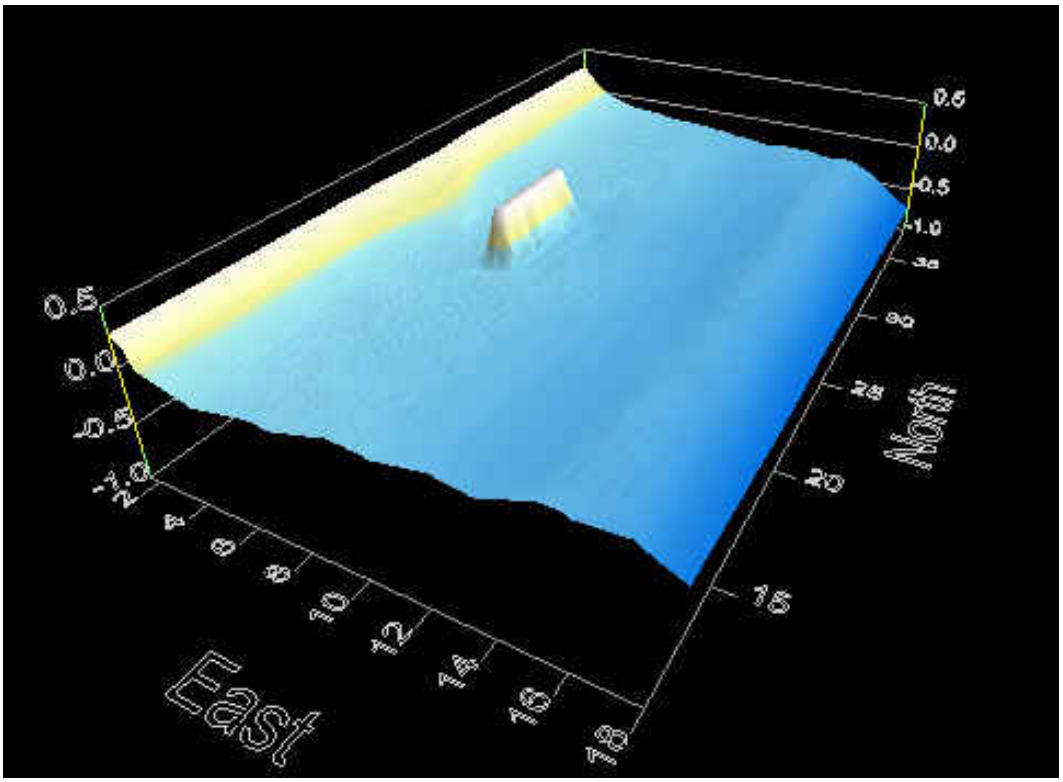


Figure 73. Post-run model beach, T2C1.

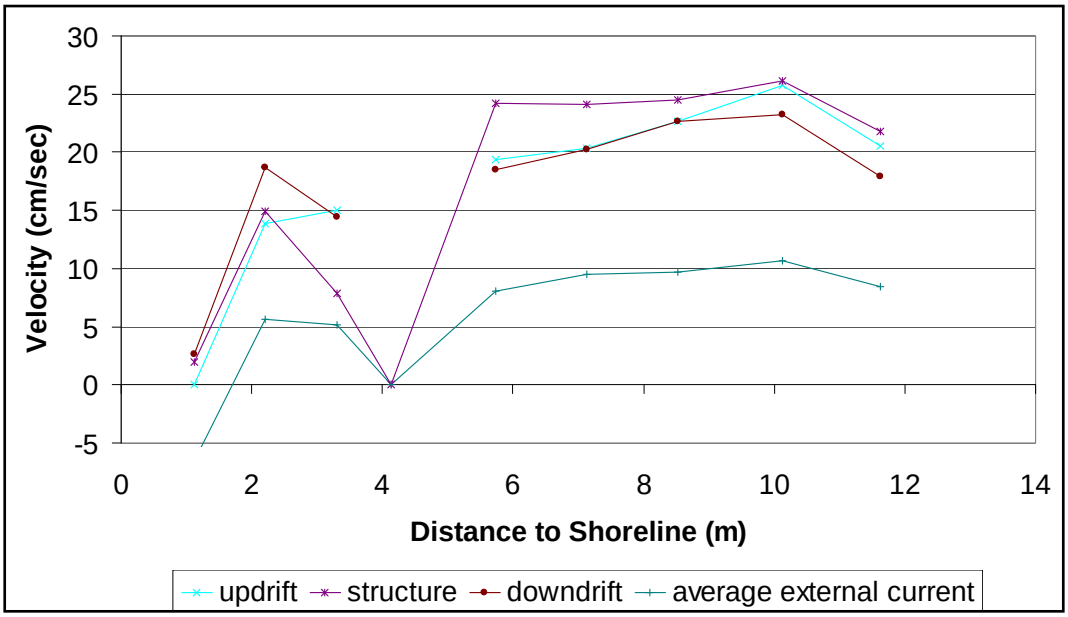


Figure 74. Cross-shore distribution of longshore current, T2C1.

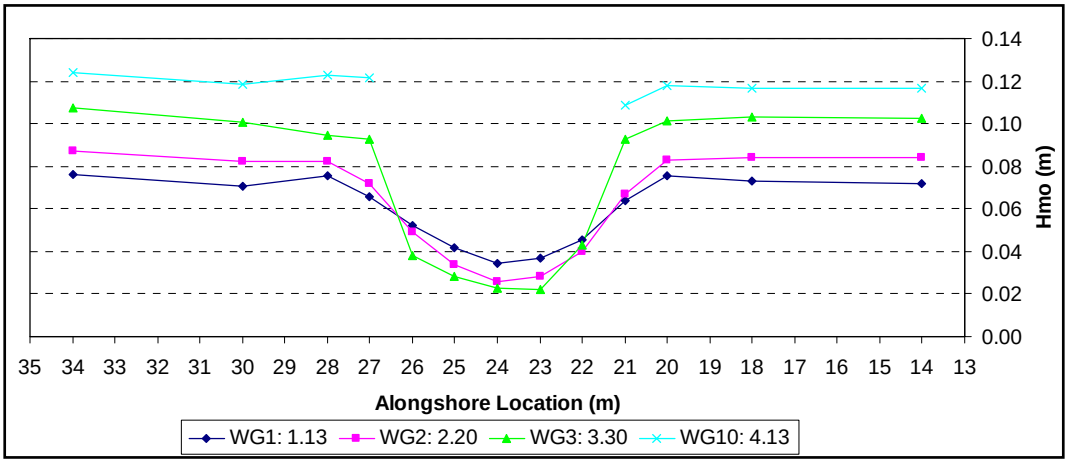


Figure 75. Distribution of wave height inshore of breakwater, T2C1.

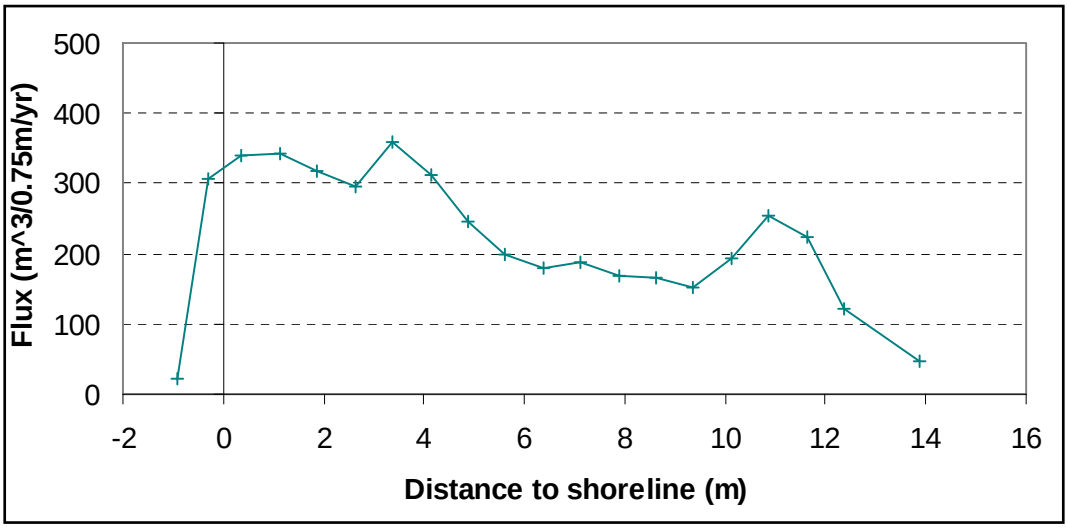


Figure 76. Cross-shore distribution of longshore sediment flux, T2C1.

T2C2

Test 2 Case 2 (T2C2) involved a 194-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T2C1. The data for this run are compiled in six files as follows:

1. T2C2.BM (BMAP file, post-run survey 53 profile lines).
2. T2C2.xyz (ASCII file, post-run survey data xyz format).
3. T2C2_current_summary.xls (Excel file, current data).
4. T2C2_wave_summary.xls (Excel file, wave data).
5. T2C2_fobs_summary.xls (Excel file, sediment concentration data).
6. T2C2_trap_summary.xls (Excel file, sediment trap data).

Figure 77 provides a DTM surface based on the post-run survey data set. The average measured cross-shore distribution of the longshore current and the imposed external longshore current is plotted in Figure 78. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 79. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 80.

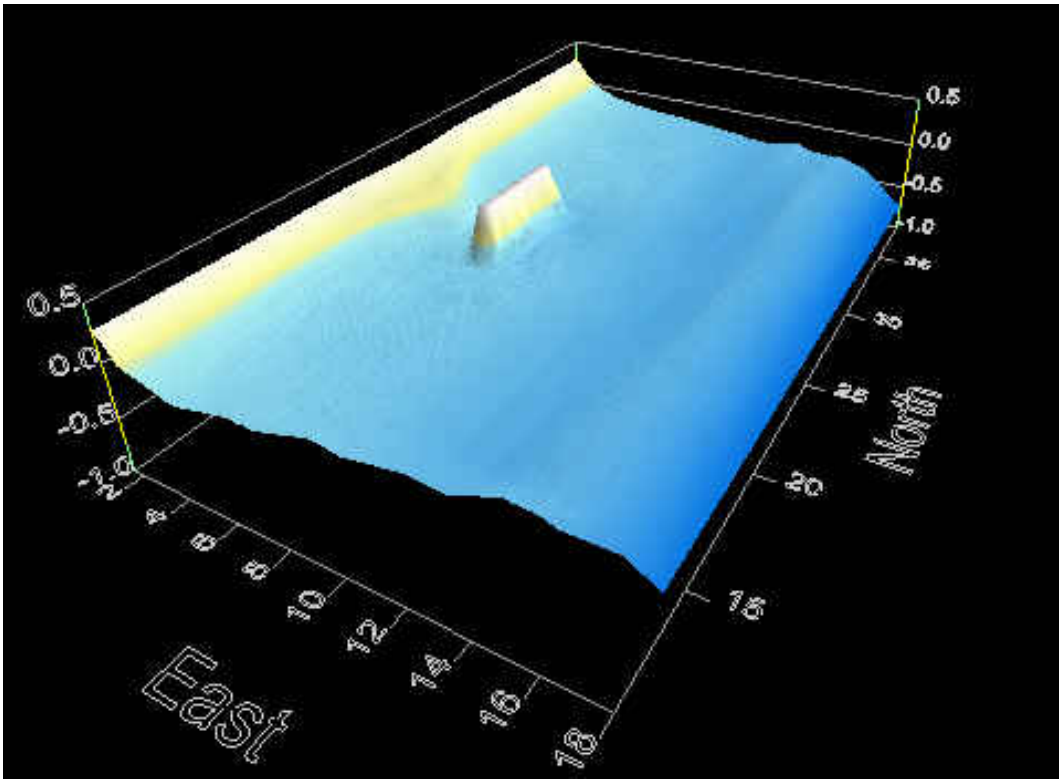


Figure 77. Post-run model beach, T2C2.

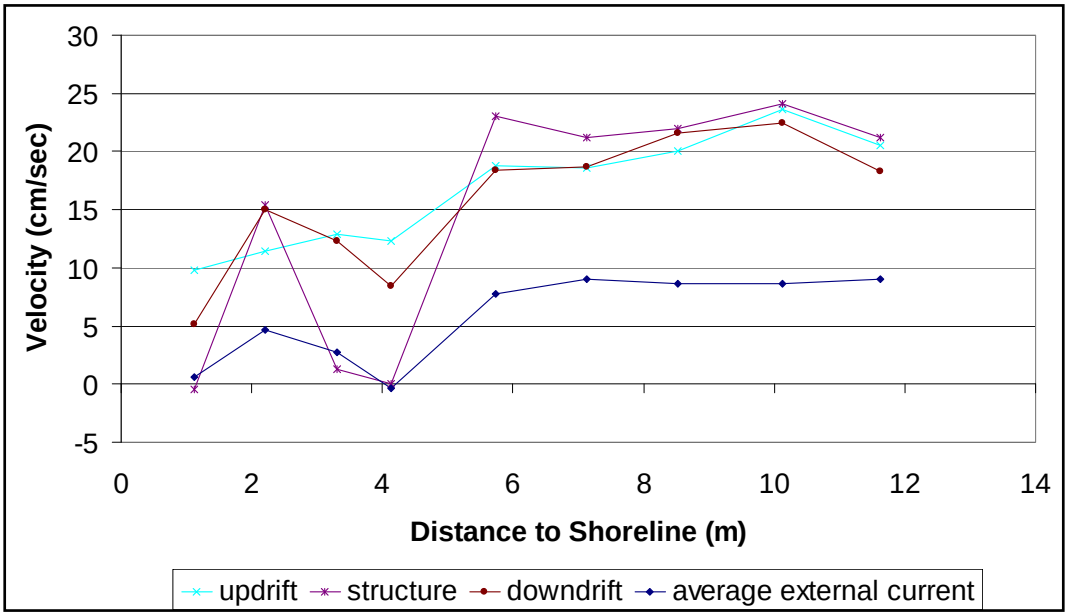


Figure 78. Cross-shore distribution of longshore current, T2C2.

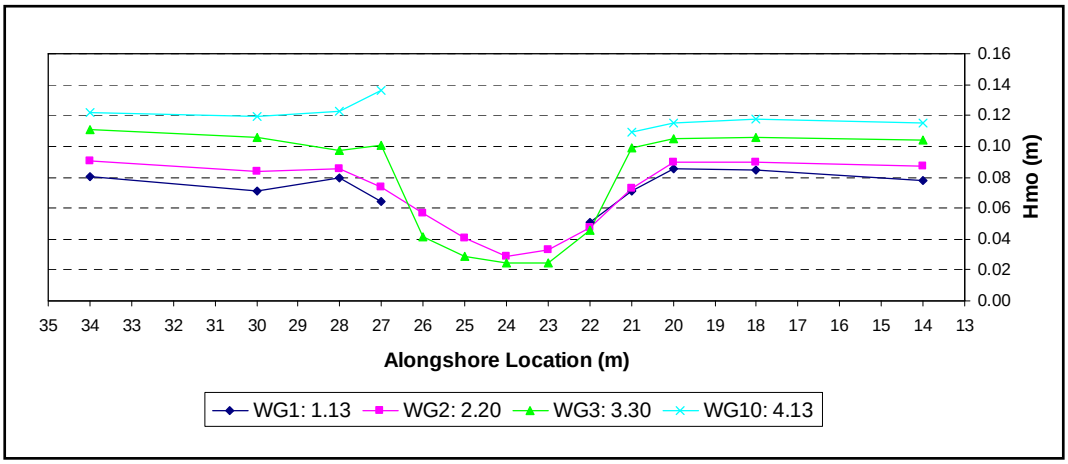


Figure 79. Distribution of wave height inshore of breakwater, T2C2.

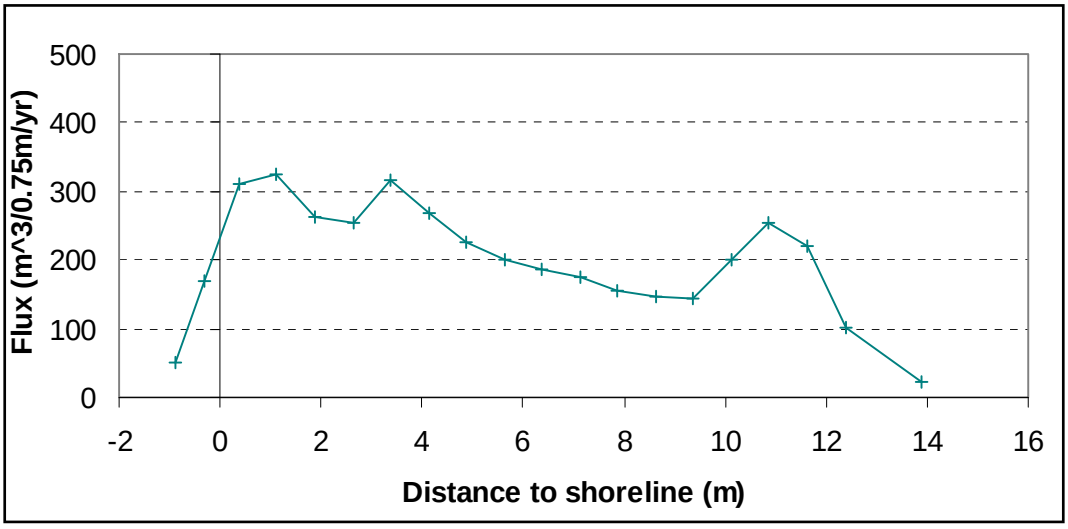


Figure 80. Cross-shore distribution of longshore sediment flux, T2C2.

T2C3

Test 2 Case 3 (T2C3) involved a 194-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T2C1. The data for this run are compiled in eight files as follows:

1. T2C3pre.BM (BMAP file, pre-run survey 53 profile lines).
2. T2C3.BM (BMAP file, post-run survey 53 profile lines).
3. T2C3p.xyz (ASCII file, pre-run survey data xyz format).
4. T2C3.xyz (ASCII file, post-run survey data xyz format).
5. T2C3_current_summary.xls (Excel file, current data).
6. T2C3_wave_summary.xls (Excel file, wave data).
7. T2C3_fobs_summary.xls (Excel file, sediment concentration data).
8. T2C3_trap_summary.xls (Excel file, sediment trap data).

Figures 81 and 82 provide images of DTM surfaces based on the pre- and post-run survey data sets. The average measured cross-shore distribution of the longshore current and the imposed external longshore current is plotted in Figure 83. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 84. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 85.

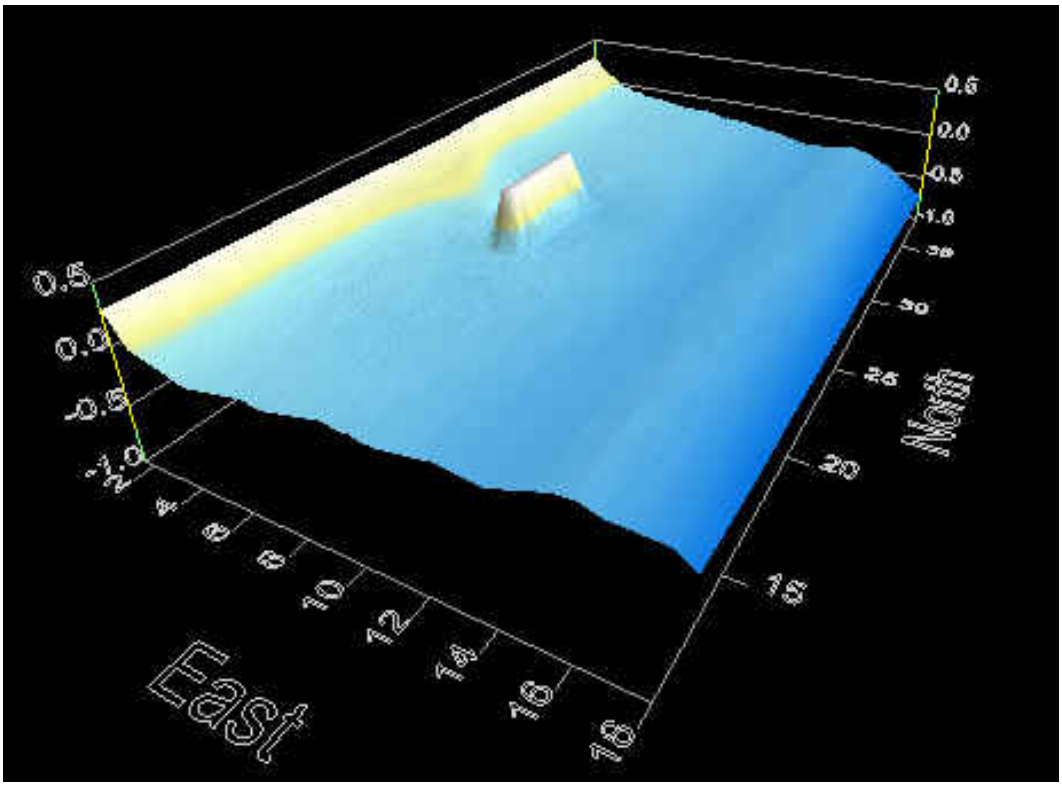


Figure 81. Initial condition model beach, T2C3.

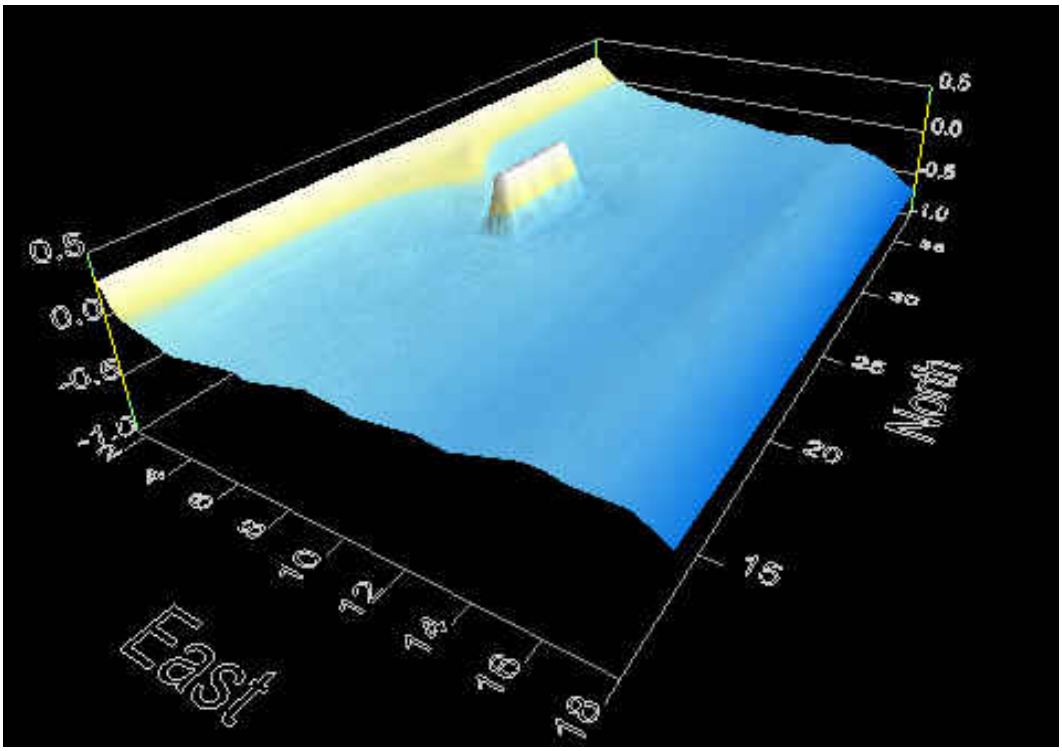


Figure 82. Post-run model beach, T2C3.

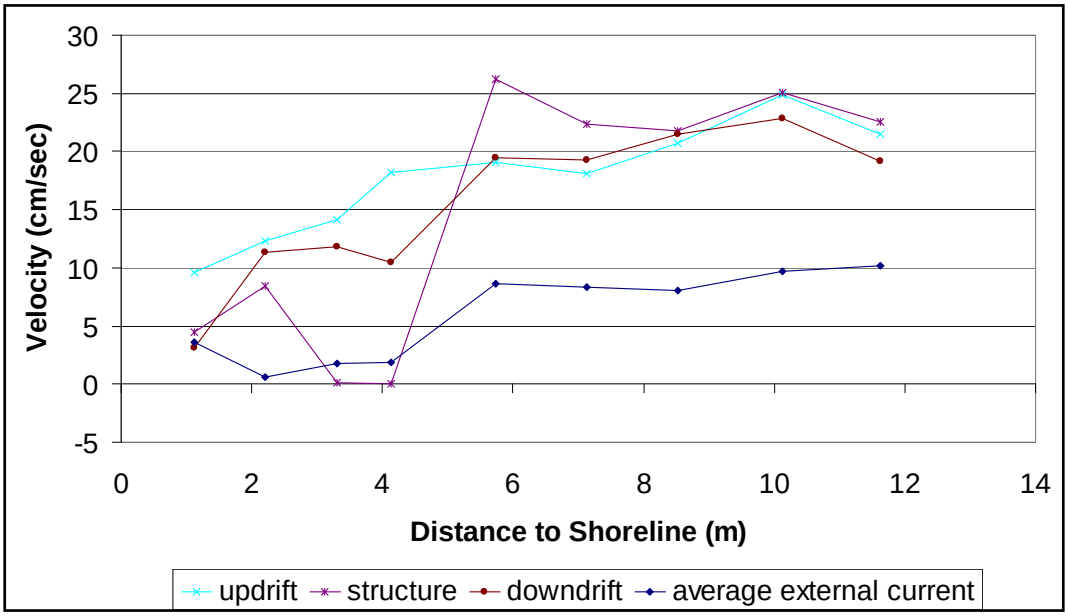


Figure 83. Cross-shore distribution of longshore current, T2C3.

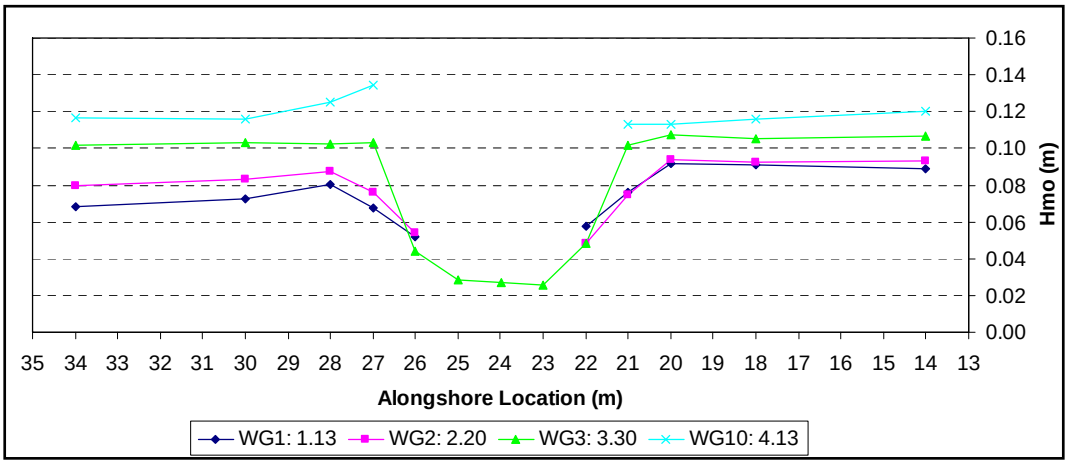


Figure 84. Distribution of wave height inshore of breakwater, T2C3.

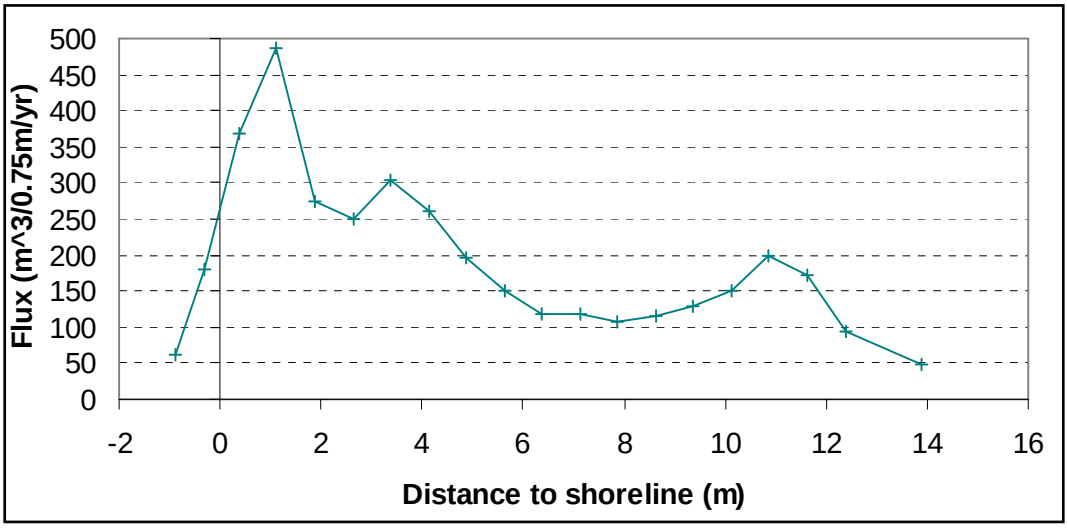


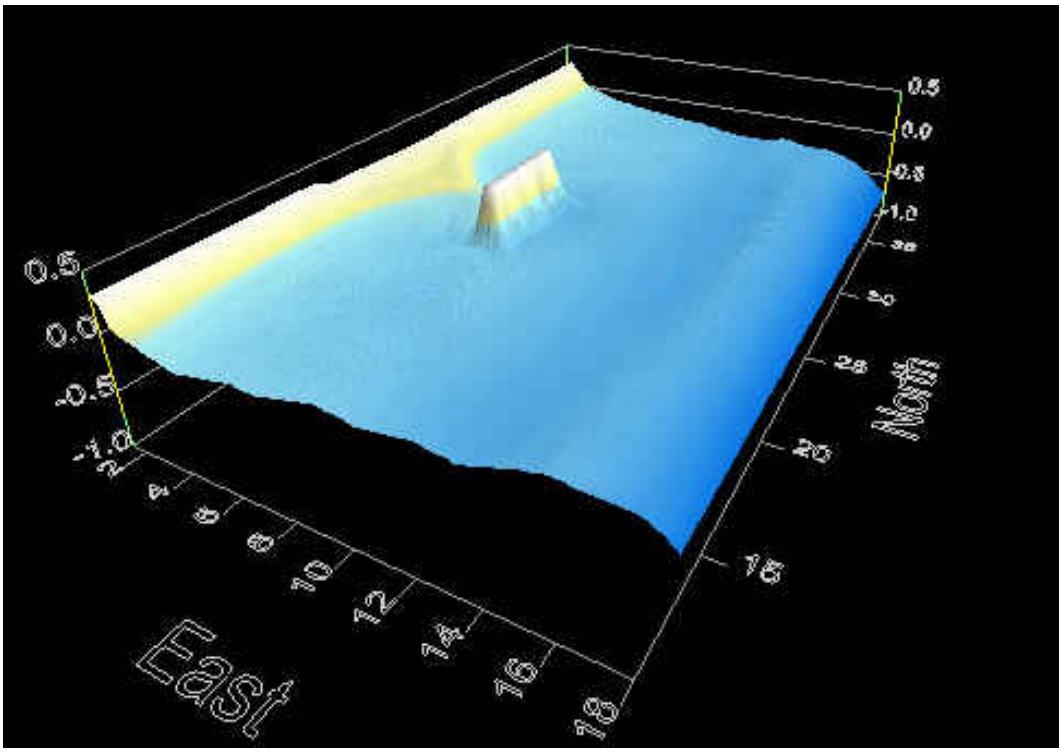
Figure 85. Cross-shore distribution of longshore sediment flux, T2C3.

T2C4

Test 2 Case 4 (T2C4) involved a 187-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T2C1. The data for this run are compiled in six files as follows:

1. T2C4.BM (BMAP file, post-run survey 53 profile lines).
2. T2C4.xyz (ASCII file, post-run survey data xyz format).
3. T2C4_current_summary.xls (Excel file, current data).
4. T2C4_wave_summary.xls (Excel file, wave data).
5. T2C4_fobs_summary.xls (Excel file, sediment concentration data).
6. T2C4_trap_summary.xls (Excel file, sediment trap data).

Figure 86 provides a DTM surface based on the post-run survey data set. The average measured cross-shore distribution of the longshore current and the imposed external longshore current is plotted in Figure 87. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 88. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 89.


0.5
0.0
-0.5
-1.0
East
2
4
6
8
10
12
14
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-20.0

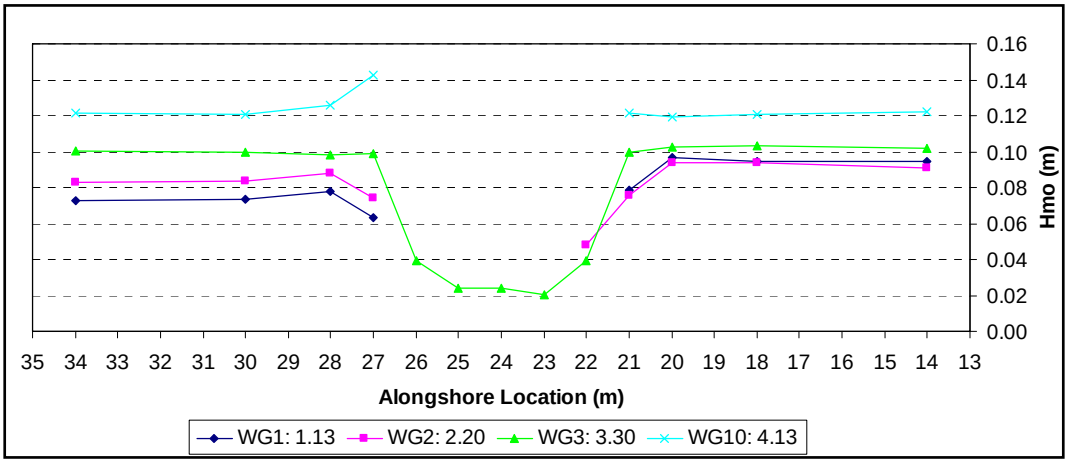

Figure 88. Distribution of wave height inshore of breakwater, T2C4.

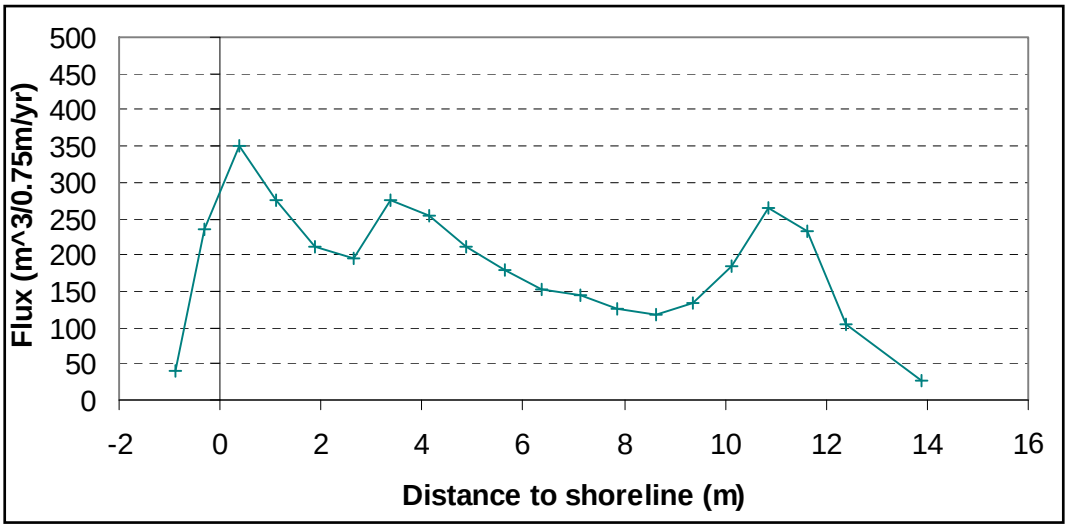

Figure 89. Cross-shore distribution of longshore sediment flux, T2C4.

T2C5

Test 2 Case 5 (T2C5) involved a 180-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T2C1. The data for this run are compiled in eight files as follows:

1. T2C5pre.BM (BMAP file, pre-run survey 39 profile lines).
2. T2C5.BM (BMAP file, 53 post-run survey profile lines).
3. T2C5p.xyz (ASCII file, pre-run survey data xyz format).
4. T2C5.xyz (ASCII file, post-run survey data xyz format).
5. T2C5_current_summary.xls (Excel file, current data).
6. T2C5_wave_summary.xls (Excel file, wave data).

7. T2C5_fobs_summary.xls (Excel file, sediment concentration data).
8. T2C5_trap_summary.xls (Excel file, sediment trap data).

Figures 90 and 91 provide images of DTM surfaces based on the pre- and post-run survey data sets. The average measured cross-shore distribution of the longshore current and the imposed external longshore current is plotted in Figure 92. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 93. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 94.

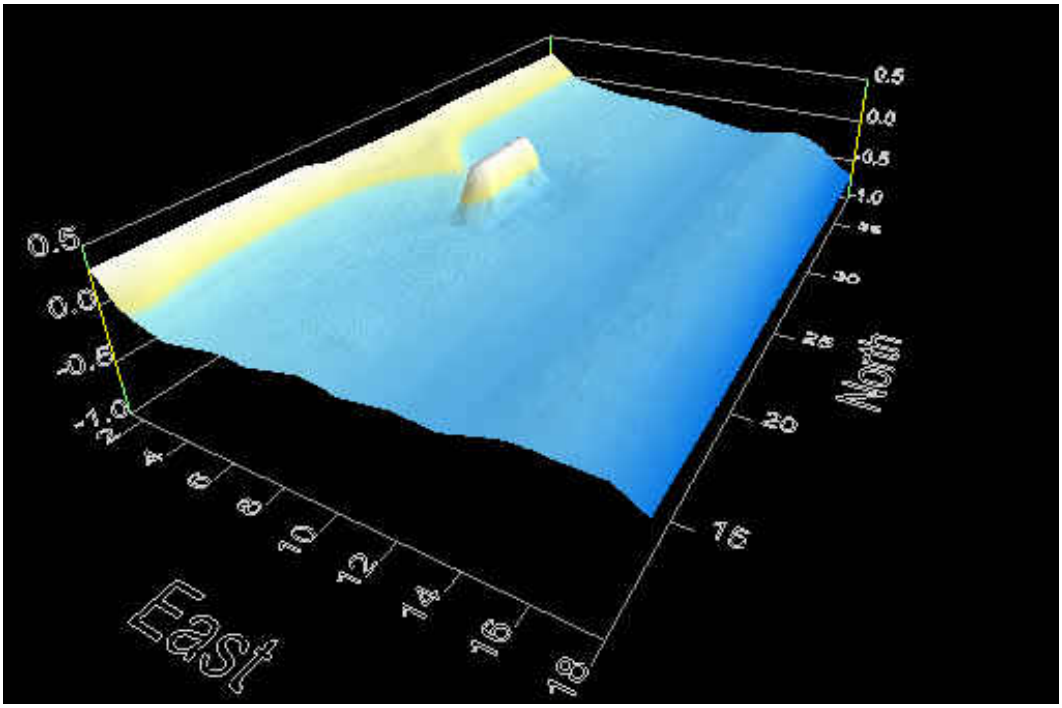

Figure 90. Initial condition model beach, T2C5.

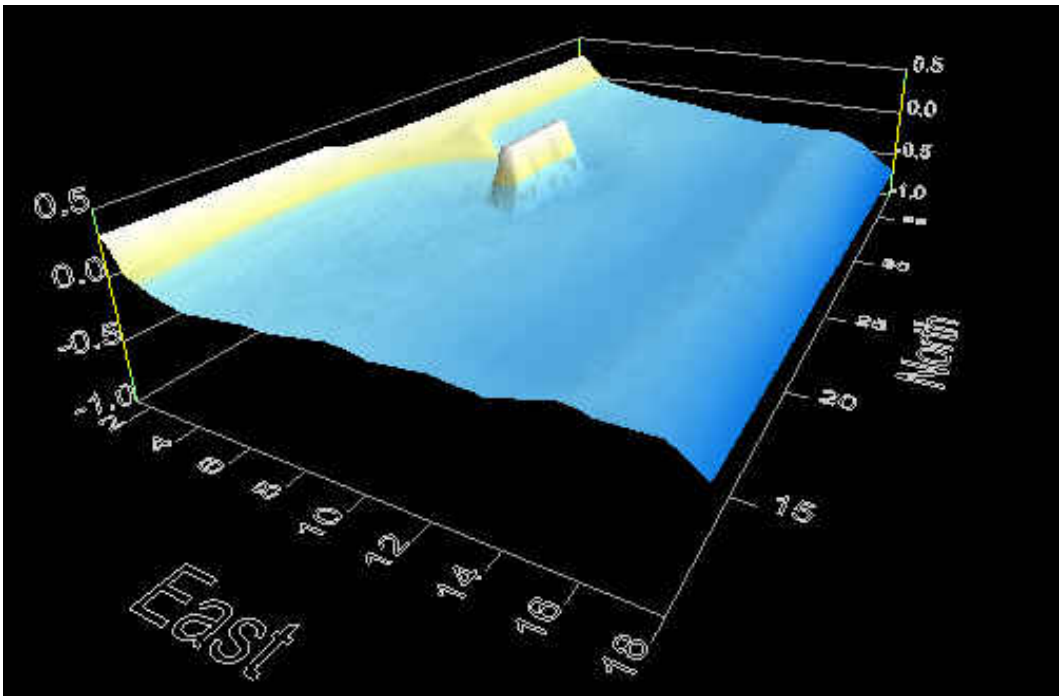

Figure 91. Post-run model beach, T2C5.

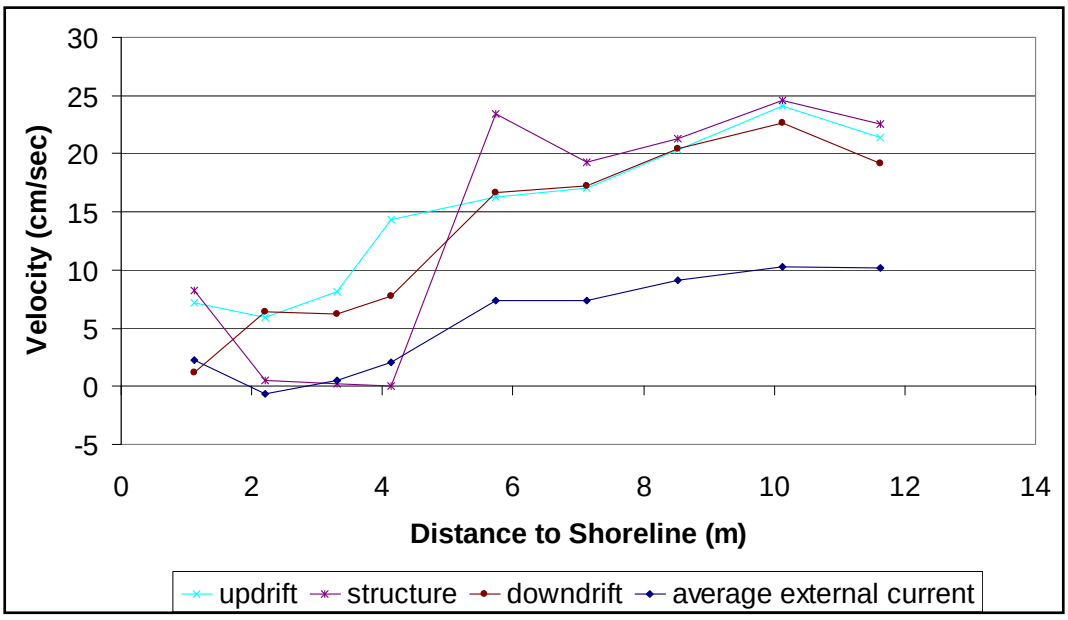

Figure 92. Cross-shore distribution of longshore current, T2C5.

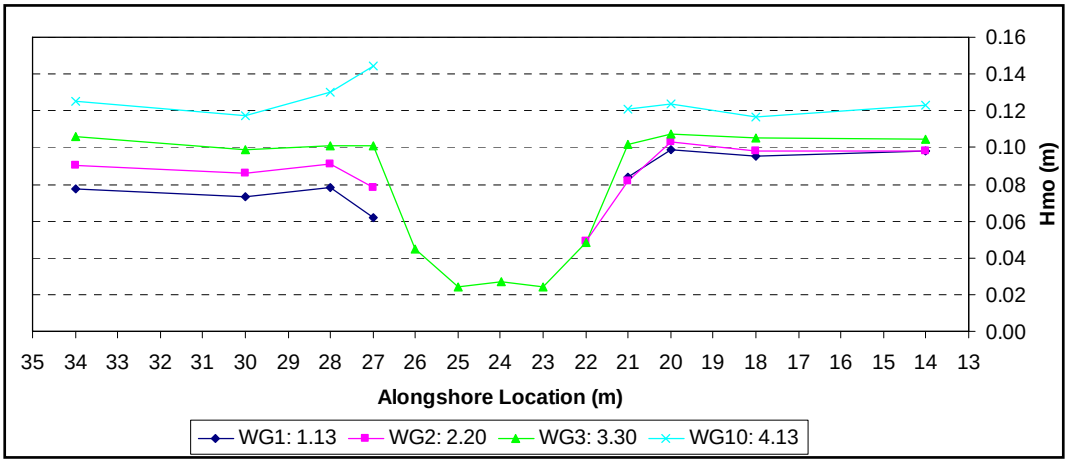

Figure 93. Distribution of wave height inshore of breakwater, T2C5.

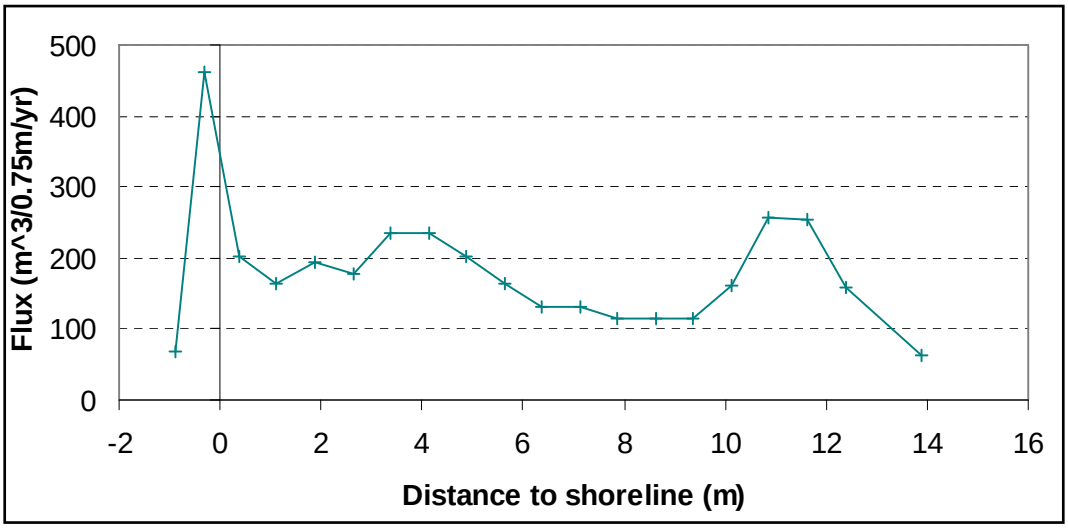

Figure 94. Cross-shore distribution of longshore sediment flux, T2C5.

T2C6

Test 2 Case 6 (T2C6) involved a 181-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T2C1. The data for this run are compiled in six files as follows:

1. T2C6.BM (BMAP file, post-run survey 53 profile lines).
2. T2C6.xyz (ASCII file, post-run survey data xyz format).
3. T2C6_current_summary.xls (Excel file, current data).
4. T2C6_wave_summary.xls (Excel file, wave data).
5. T2C6_fobs_summary.xls (Excel file, sediment concentration data).
6. T2C6_trap_summary.xls (Excel file, sediment trap data).

Figure 95 provides a DTM surface based on the post-run survey data set. The average measured cross-shore distribution of the longshore current and the imposed external longshore current is plotted in Figure 96. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 97. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 98.

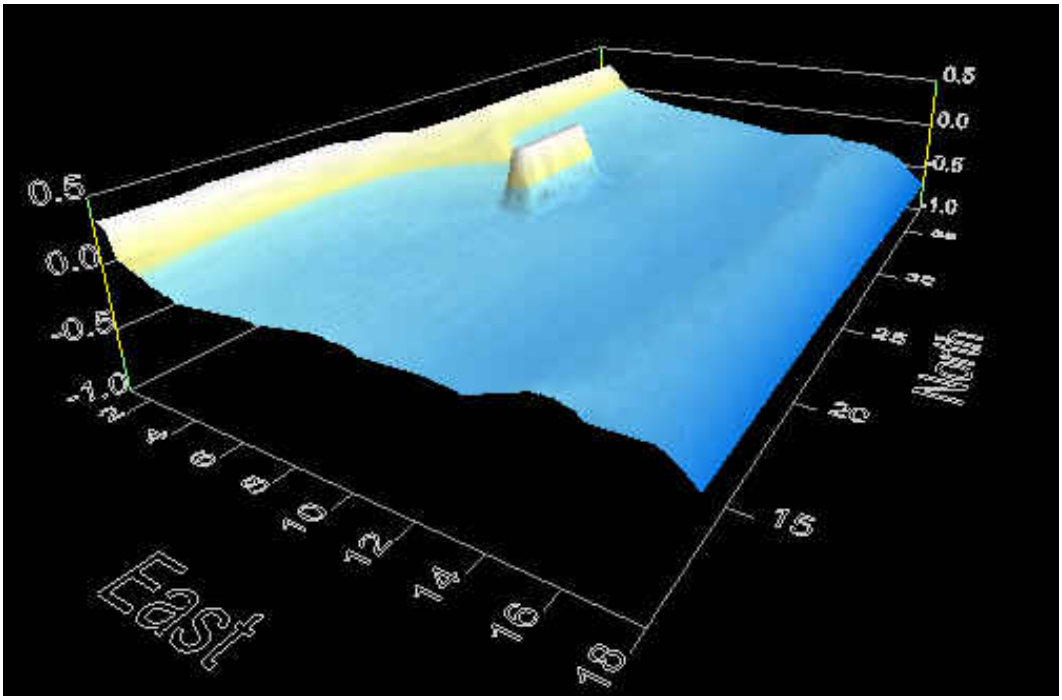

Figure 95. Post-run model beach, T2C6.

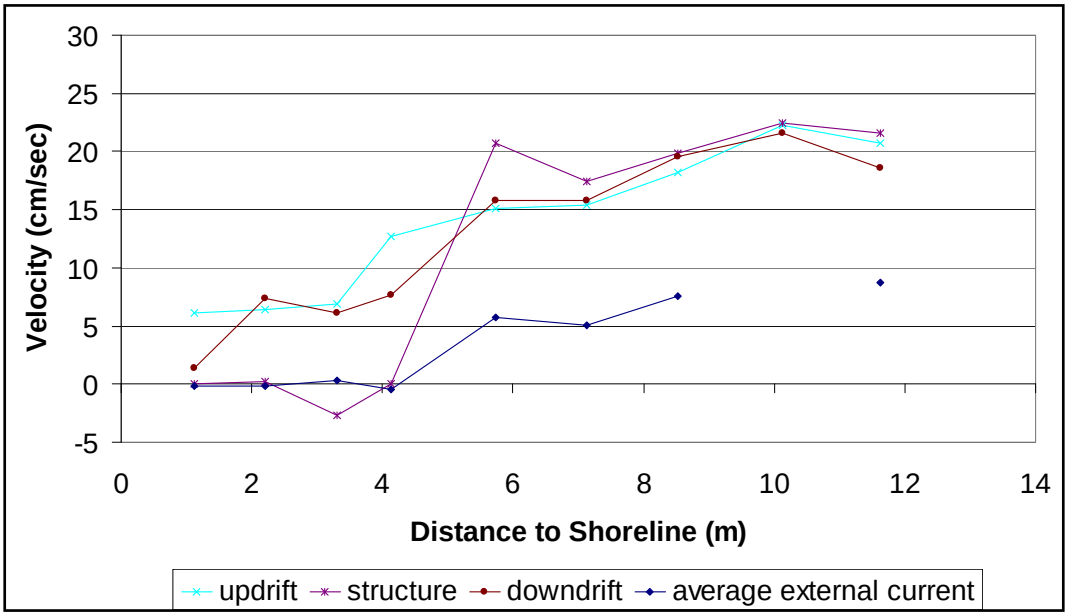

Figure 96. Cross-shore distribution of longshore current, T2C6.

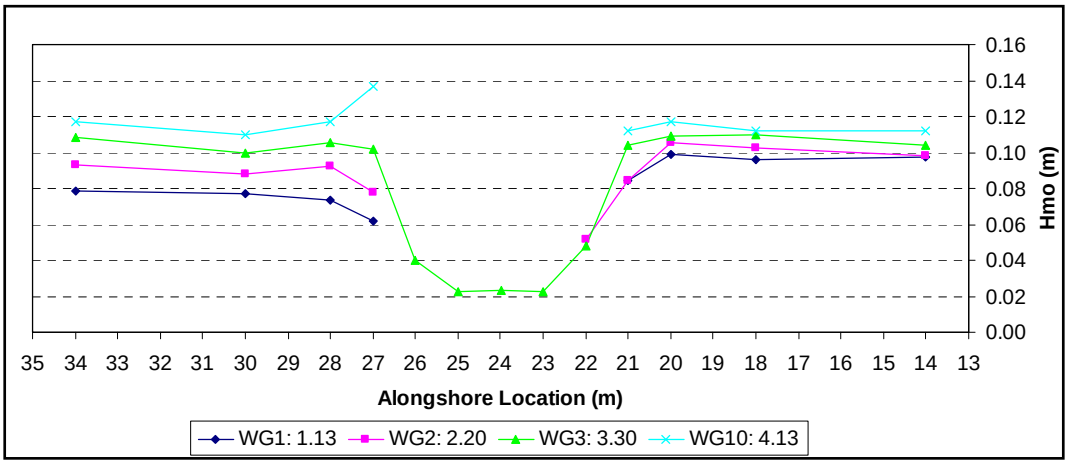

Figure 97. Distribution of wave height inshore of breakwater, T2C6.

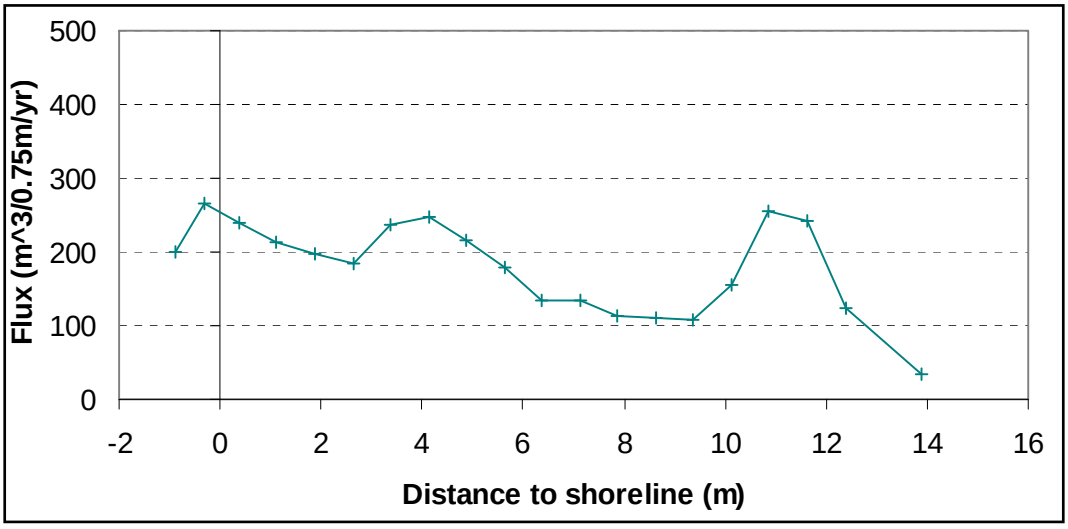

Figure 98. Cross-shore distribution of longshore sediment flux, T2C6.

T2C7

Test 2 Case 7 (T2C7) involved a 186-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T2C1. The data for this run are compiled in eight files as follows:

1. T2C7pre.BM (BMAP file, pre-run survey 39 profile lines).
2. T2C7.BM (BMAP file, post-run survey 53 profile lines).
3. T2C7p.xyz (ASCII file, pre-run survey data xyz format).
4. T2C7.xyz (ASCII file, post-run survey data xyz format).
5. T2C7_current_summary.xls (Excel file, current data).
6. T2C7_wave_summary.xls (Excel file, wave data).
7. T2C7_fobs_summary.xls (Excel file, sediment concentration data).
8. T2C7_trap_summary.xls (Excel file, sediment trap data).

Figures 99 and 100 provide images of DTM surfaces based on the pre- and post-run survey data sets. The average measured cross-shore distribution of the longshore current and the imposed external longshore current is plotted in Figure 101. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 102. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 103.

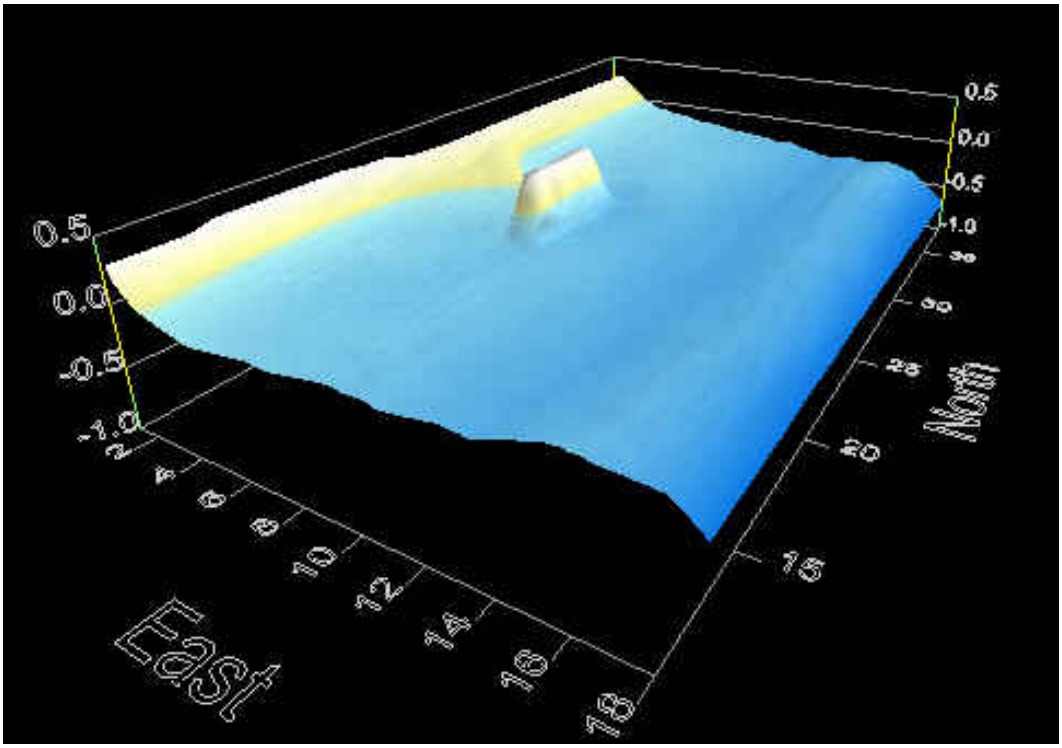

Figure 99. Initial condition model beach, T2C7.

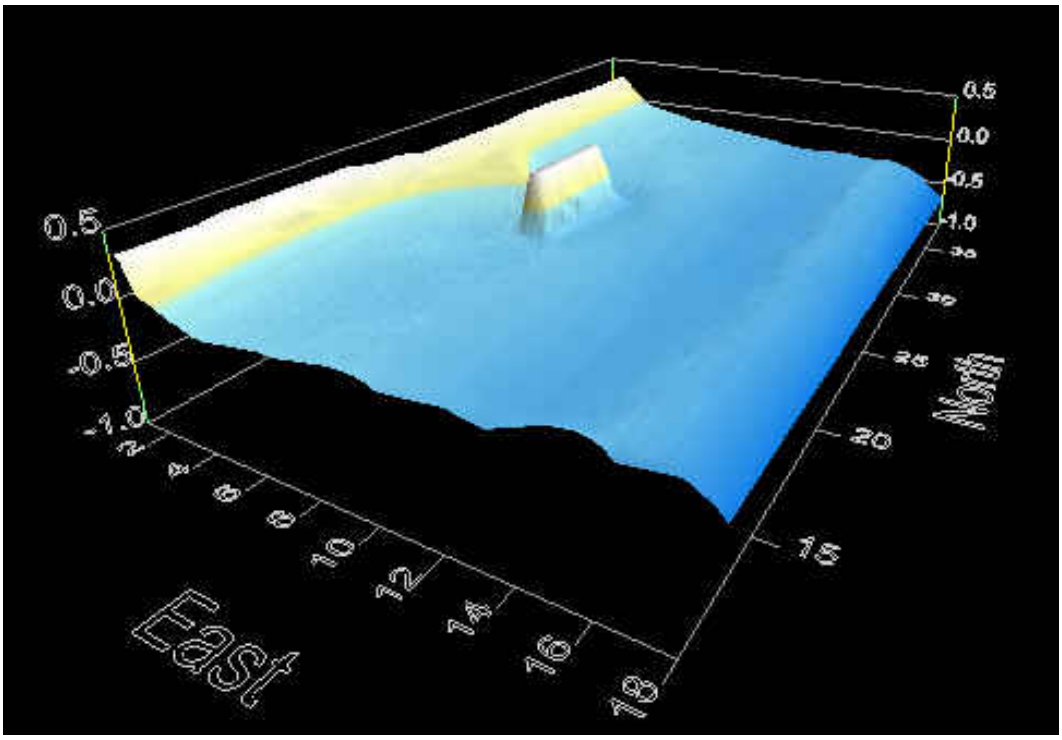

Figure 100. Post-run model beach, T2C7.

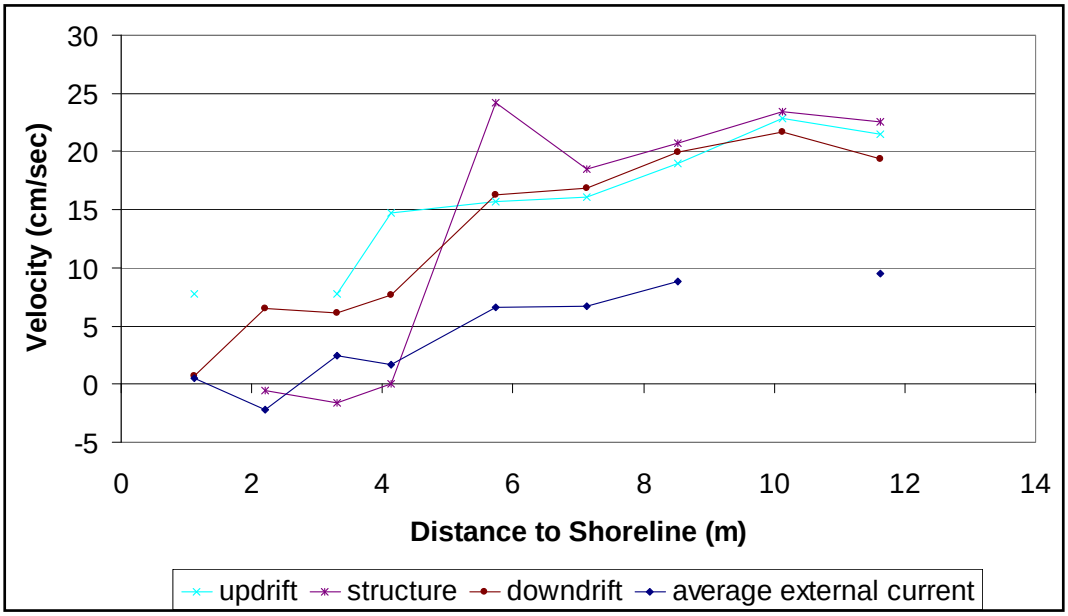

Figure 101. Cross-shore distribution of longshore current, T2C7.

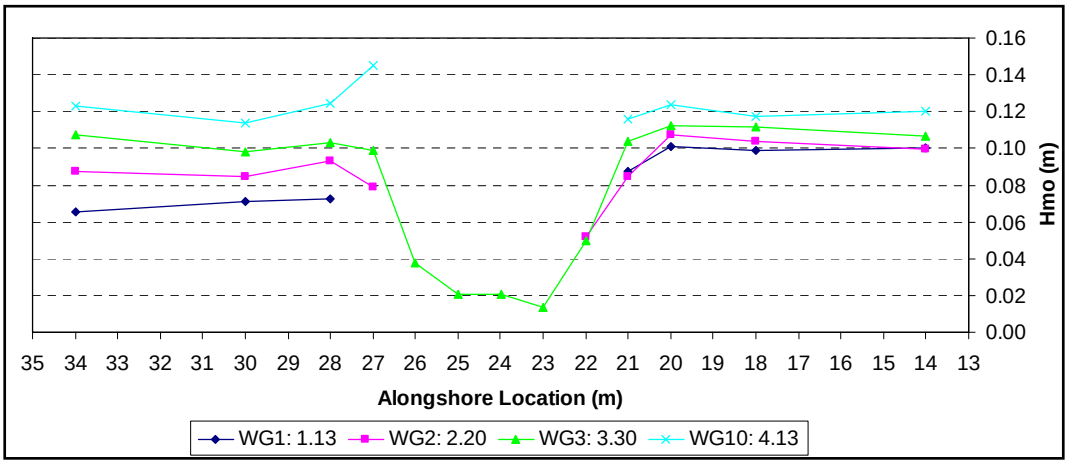

Figure 102. Distribution of wave height inshore of breakwater, T2C7.

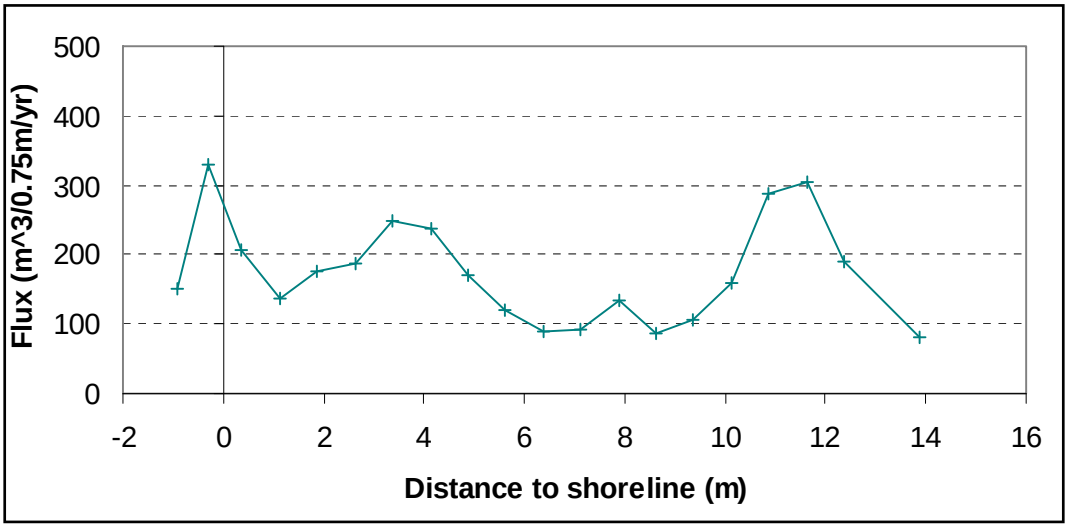

Figure 103. Cross-shore distribution of longhshore sediment flux, T2C7.

T2C8

Test 2 Case 8 (T2C8) involved a 197-min run with waves and currents. Wave, current, and vertical sediment concentration were sampled at the same 13 cross-shore transects as in T2C1. The data for this run are compiled in six files as follows:

1. T2C8.BM (BMAP file, post-run survey 53 profile lines).
2. T2C8.xyz (ASCII file, post-run survey data xyz format).
3. T2C8_current_summary.xls (Excel file, current data).
4. T2C8_wave_summary.xls (Excel file, wave data).
5. T2C8_fobs_summary.xls (Excel file, sediment concentration data).
6. T2C8_trap_summary.xls (Excel file, sediment trap data).

Figure 104 provides a DTM surface based on the post-run survey data set. At the end of this run the salient had advanced to within about 10 cm of the breakwater, Figure 105. The average measured cross-shore distribution of the longshore current and the imposed external longshore current is plotted in Figure 106. The alongshore distribution of the measured significant wave height inshore of the breakwater is plotted in Figure 107. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 108.

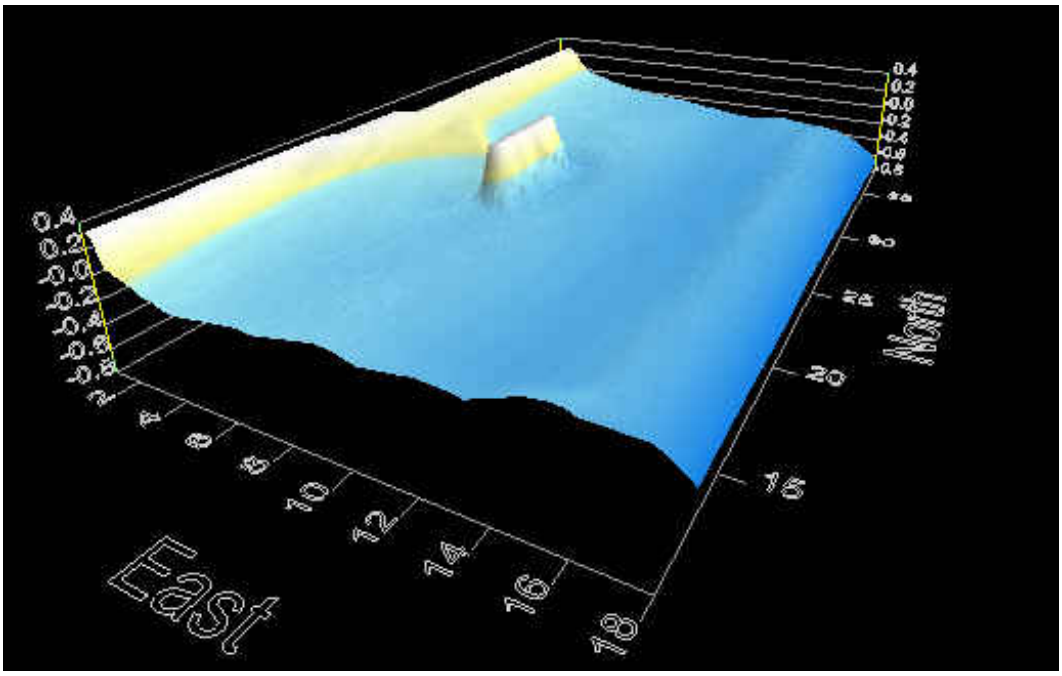

Figure 104. Post-run model beach, T2C8.

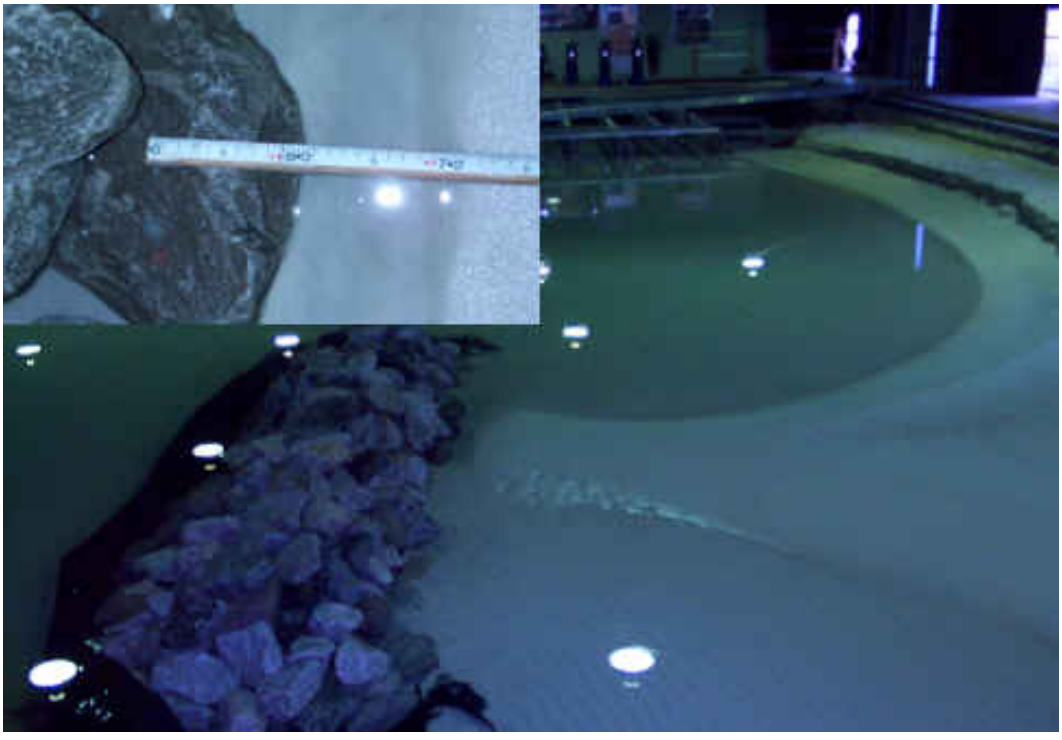

Figure 105. Final salient development, T2C8.

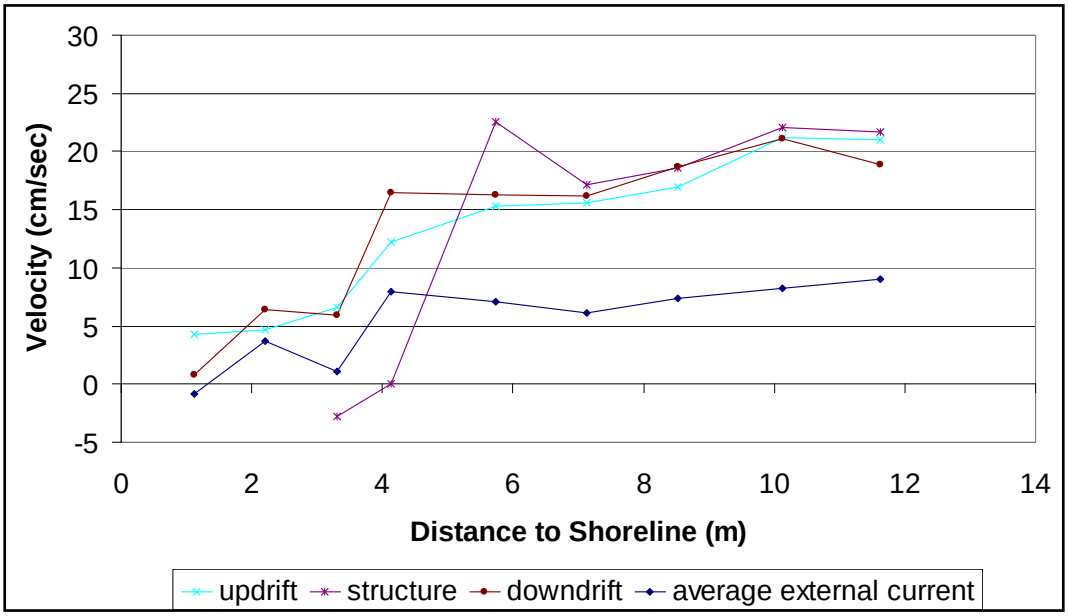

Figure 106. Cross-shore distribution of longshore current, T2C8.

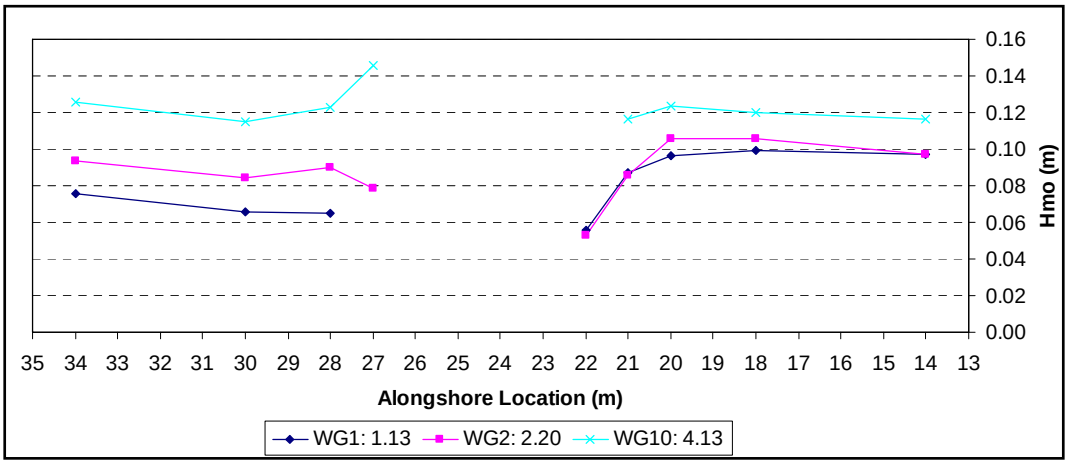

Figure 107. Distribution of wave height inshore of breakwater, T2C8.

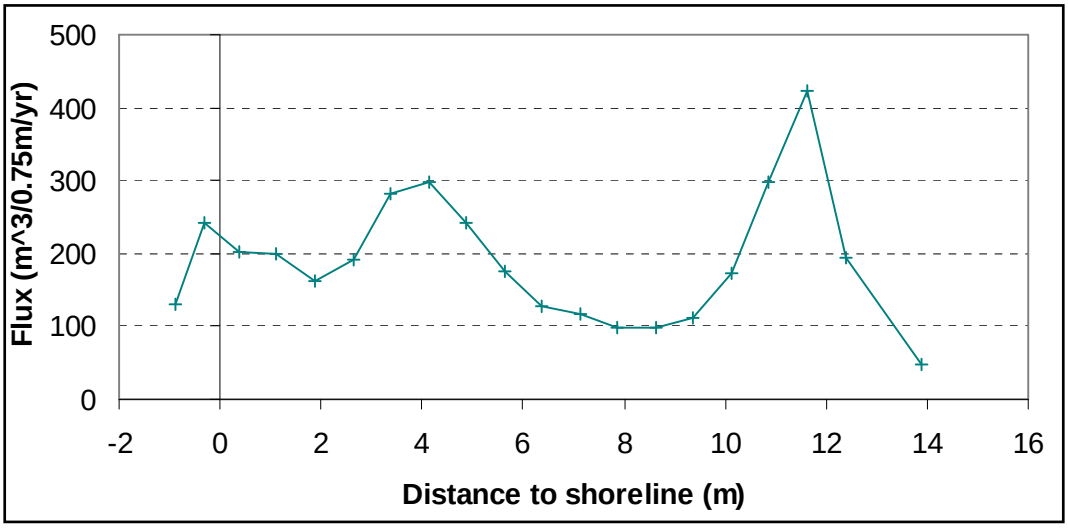

Figure 108. Cross-shore distribution of longshore sediment flux, T2C8.

4 Test 3 Experiments

The Test 3 experiments were performed to assemble data sets for testing and validation of numerical model algorithms for development of tombolos in the lee of T-head groins. These experiments were executed in a series of six runs of approximately 180 min each on a natural beach with a T-groin headland structure centrally located in the alongshore direction of the model beach. The shore-parallel head section of the T-groin was 4 m long and positioned 4 m offshore of the initial shoreline position (Figure 2). The stem section of the T-groin was positioned at the center of the head section of the structure. In all of the Test 3 runs, the estimated wave-generated longshore flux of water was recirculated from the downstream end to the upstream end of the model beach using the LSTF's external recirculation system.

T-groin construction

A T-head rubble-mound groin was constructed in the LSTF model beach. The shore-parallel head section of the T-groin was positioned approximately between alongshore position Y = 22 m and Y = 26 m and at cross-shore position X = 7 m (4 m offshore of the initial shoreline position at X = 3 m). The movable bed sand beach was excavated down to the concrete bed and three rows of 10 concrete blocks were laid down to form the foundation of the head section of the T-groin, two rows of 12 concrete blocks were laid down to form the stem section of the T-groin (Figure 109). The area around the breakwater foundation was backfilled including the voids in the concrete blocks and filter cloth was laid over the breakwater foundation (Figure 110). A trench approximately 12 cm deep was dug around the breakwater foundation, and the edges of the filter cloth were placed in the trench and backfilled. Two rows of 10 concrete blocks were placed on top of the filter cloth on the head section, and a single row of 12 concrete blocks was placed on top of the filter cloth on the stem section (Figure 111). The voids in the blocks were filled with sand. A third and final course of concrete blocks was stacked on top of the second layer of blocks and sand filled (Figure 112). The concrete block T-groin core was covered with two layers of riprap stone to complete construction of the T-groin structure (Figures 113 and 114).

Figure 109. T-groin foundation and core.

Figure 110. T-groin foundation backfilled with sand.

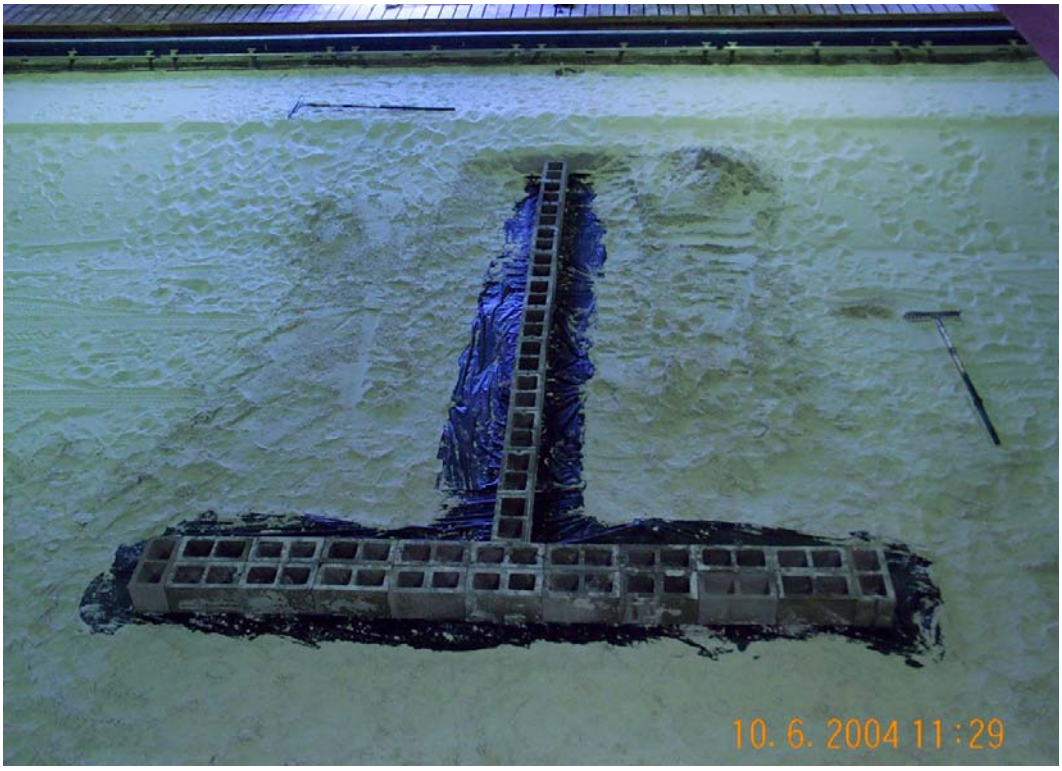

Figure 111. Filter cloth covering foundation and second layer concrete block core.

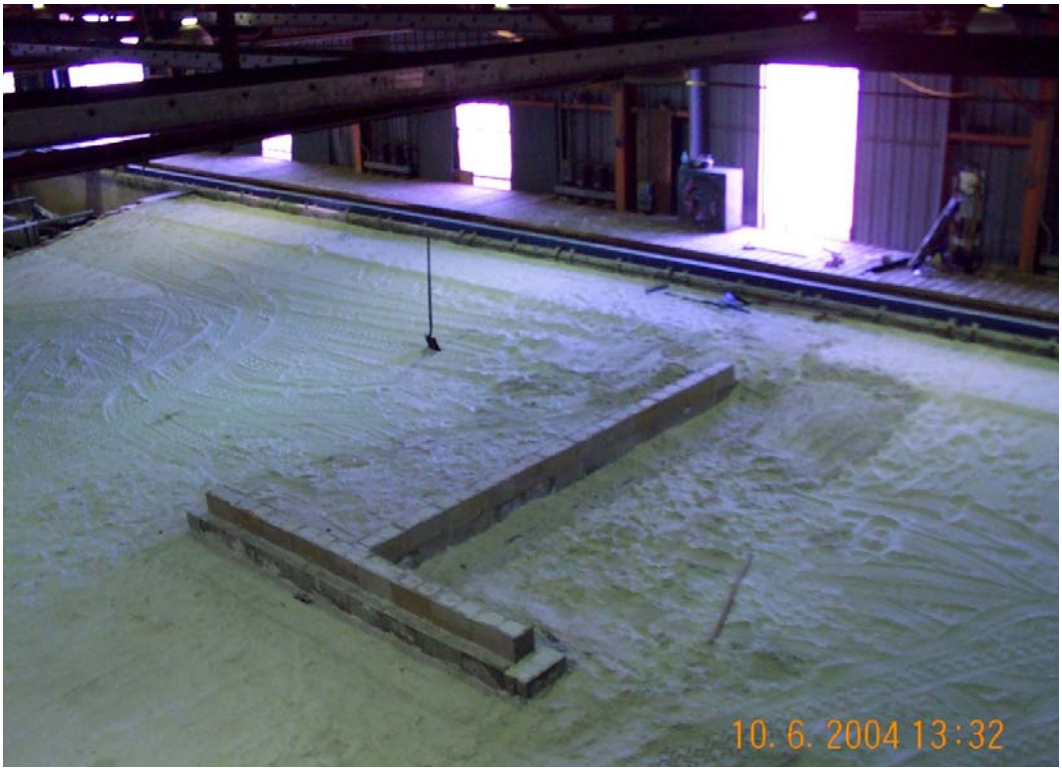

Figure 112. Third layer concrete block T-groin core.

Figure 113. Completed T-groin structure in LSTF model beach.

Figure 114. T-groin structure in filled LSTF at operating water level.

T3C1

Test 3 Case 1 (T3C1) involved a 178-min run with waves and currents. Waves and currents were sampled at 13 cross-shore transects (alongshore positions 14, 18, 30, 34, and at 1-m intervals between alongshore position 20 and 28). The data for this run are compiled in seven files as follows:

1. T3C1p.BM (BMAP file, pre-run survey 50 profile lines).
2. T3C1.BM (BMAP file, post-run survey 29 profile lines).
3. T3C1p.xyz (ASCII file, pre-run survey data xyz format).
4. T3C1.xyz (ASCII file, post-run survey data xyz format).
5. T3C1_current_summary.xls (Excel file, current data).
6. T3C1_wave_summary.xls (Excel file, wave data).
7. T3C1_trap_summary.xls (Excel file, sediment trap data).

Figures 115 and 116 provide images of DTMs based on the pre and post-run survey data sets. The average measured cross-shore distribution of the longshore current in three regions, updrift of the structure (measurements taken at Y = 27, 28, 30, and 34), at the structure (measurements taken at Y = 22, 23, 24, 25, and 26), and downdrift of the structure (measurements taken at Y = 14, 18, 20, and 21), is plotted in Figure 117. The alongshore distribution of the measured significant wave height inshore of the T-groin is plotted in Figure 118. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 119.

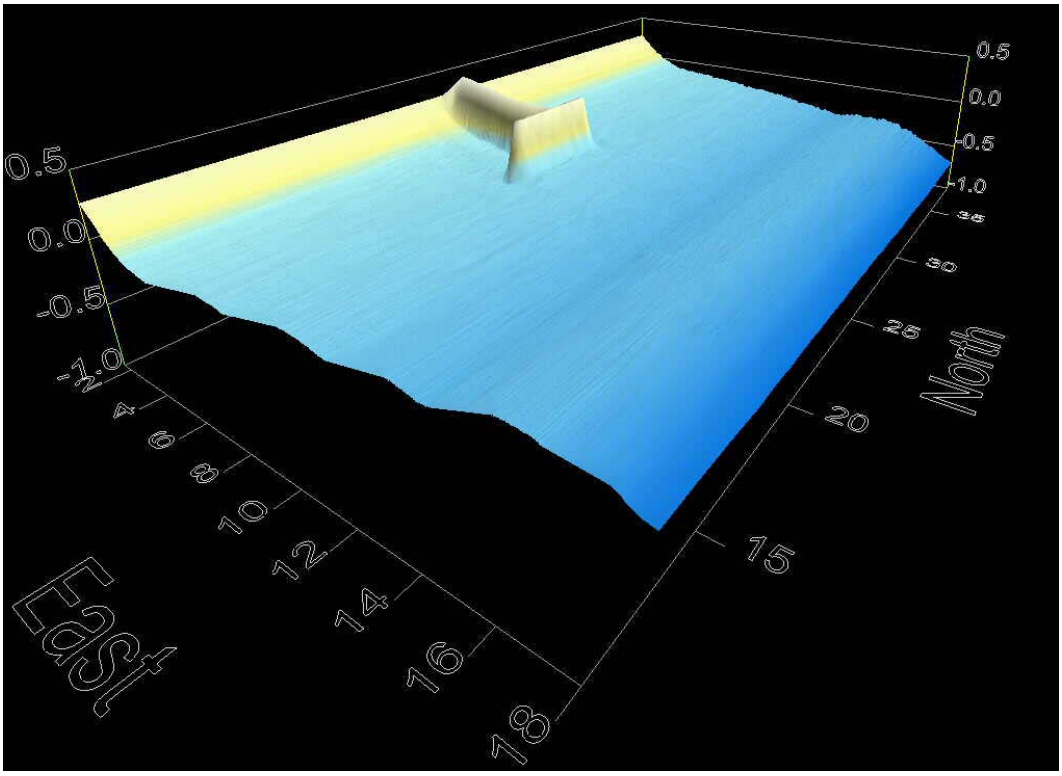

Figure 115. Initial condition model beach, T3C1.

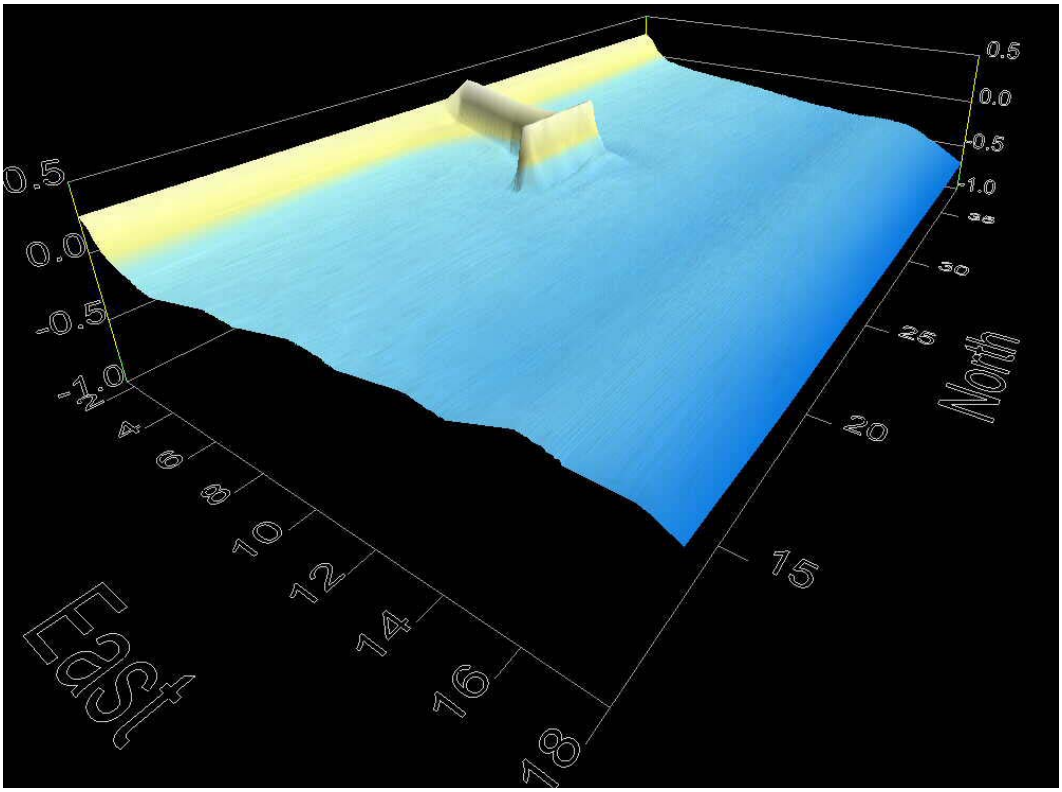

Figure 116. Post-run model beach, T3C1.

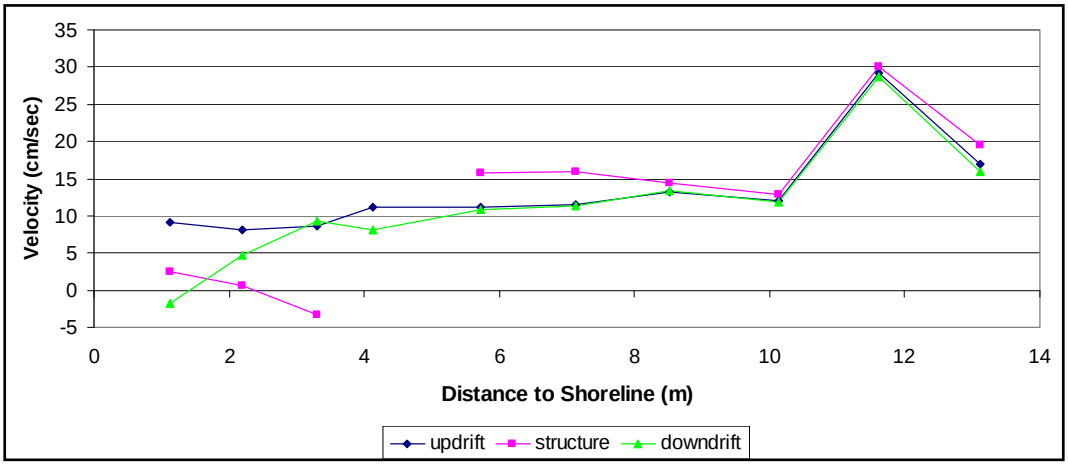

Figure 117. Cross-shore distribution of longshore current, T3C1.

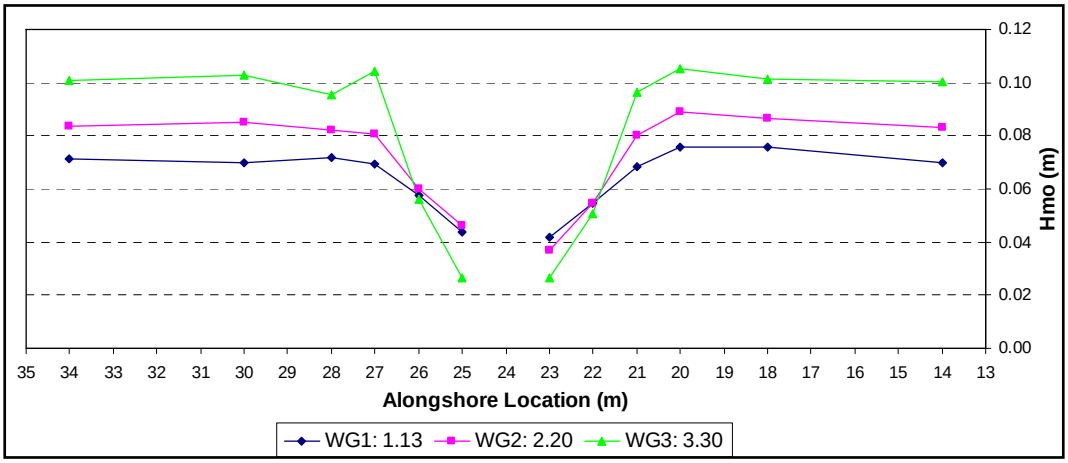

Figure 118. Distribution of wave height inshore of T-groin, T3C1.

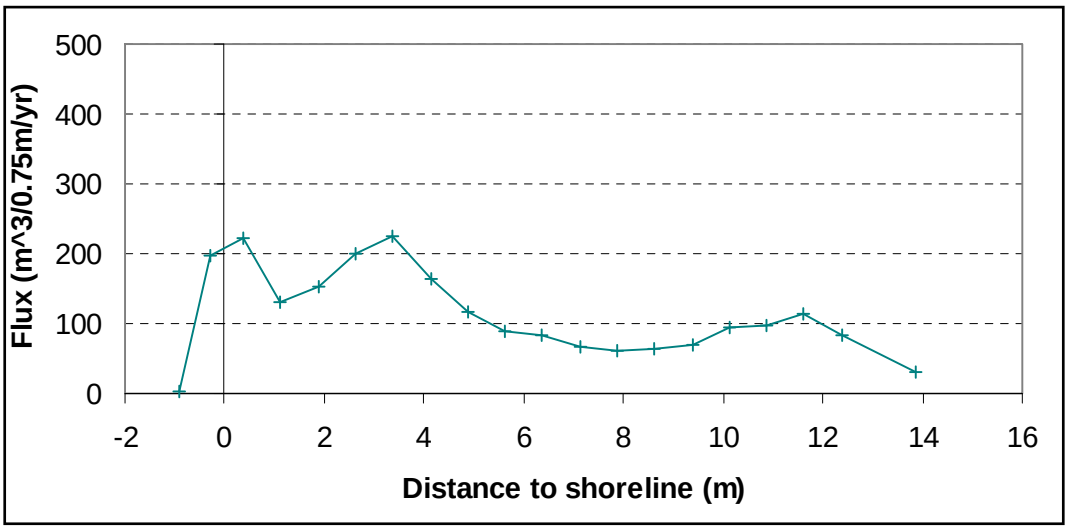

Figure 119. Cross-shore distribution of longshore sediment flux, T3C1.

T3C2

Test 3 Case 2 (T3C2) involved a 182-min run with waves and currents. Waves and currents were sampled at the same 13 cross-shore transects as in T3C1. The data for this run are compiled in five files as follows:

1. T3C2.BM (BMAP file, post-run survey 50 profile lines).
2. T3C2.xyz (ASCII file, post-run survey data xyz format).
3. T3C2_current_summary.xls (Excel file, current data).
4. T3C2_wave_summary.xls (Excel file, wave data).
5. T3C2_trap_summary.xls (Excel file, sediment trap data).

A DTM surface based on the post-run survey data is plotted in Figure 120. After 6 hr of waves and currents, shoreline sailents extended approximately 1.5 m seaward of the initial shoreline position both updrift and downdrift of the T-groin stem. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 121. The alongshore distribution of the measured significant wave height inshore of the T-groin is plotted in Figure 122. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 123.

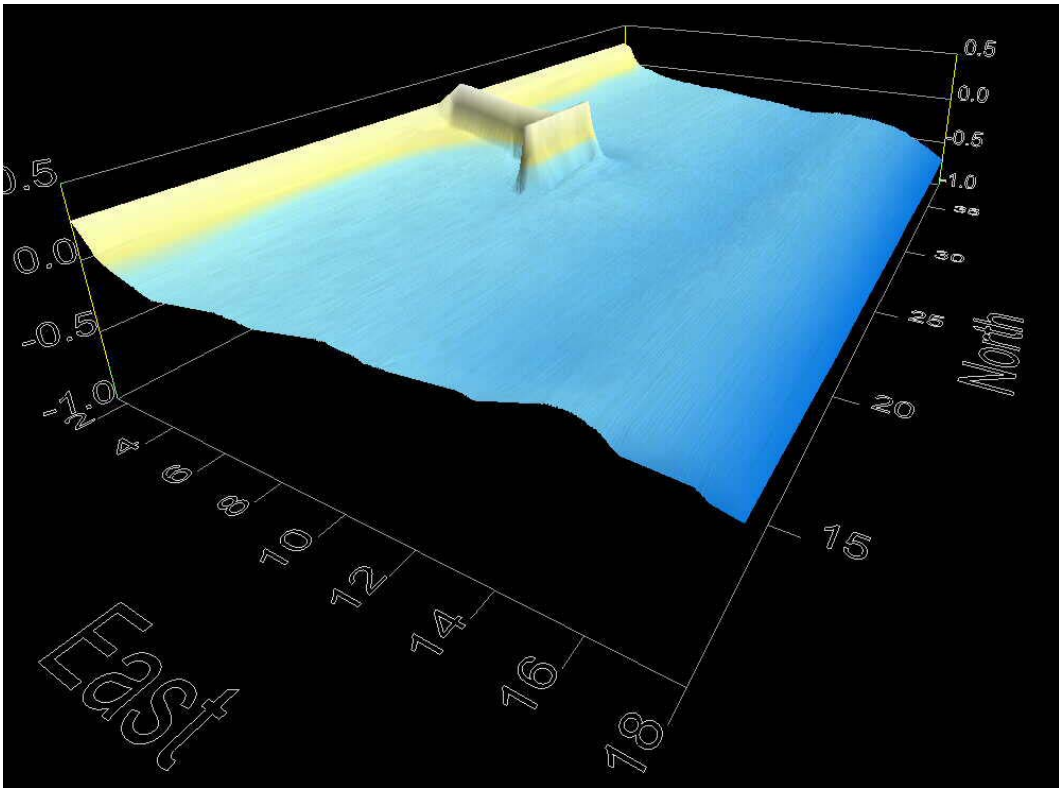

Figure 120. Post-run model beach, T3C2.

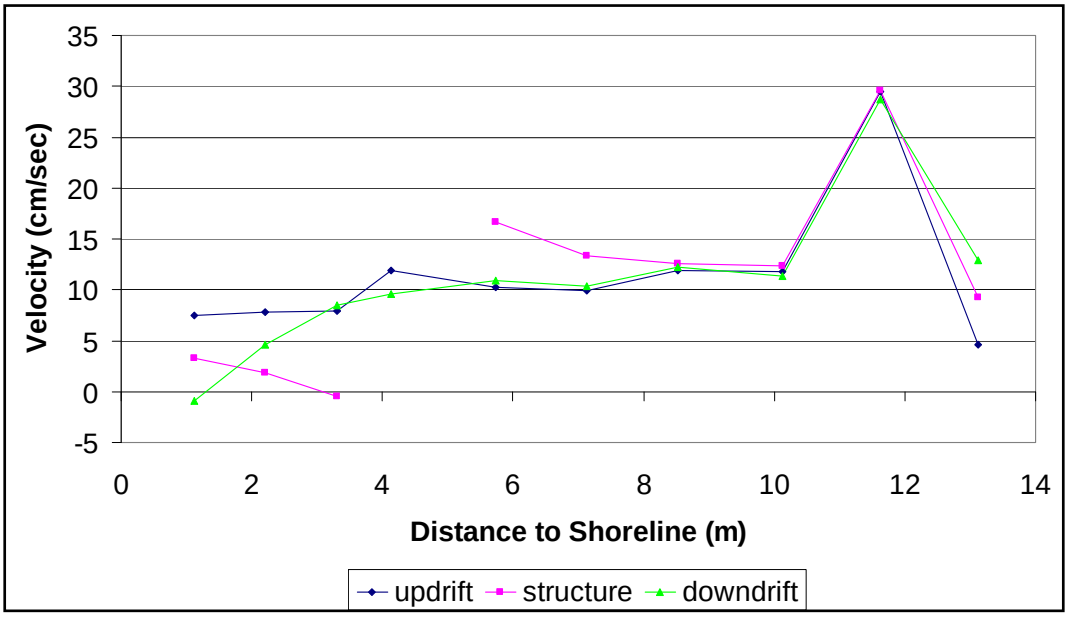

Figure 121. Cross-shore distribution of longshore current, T3C2.

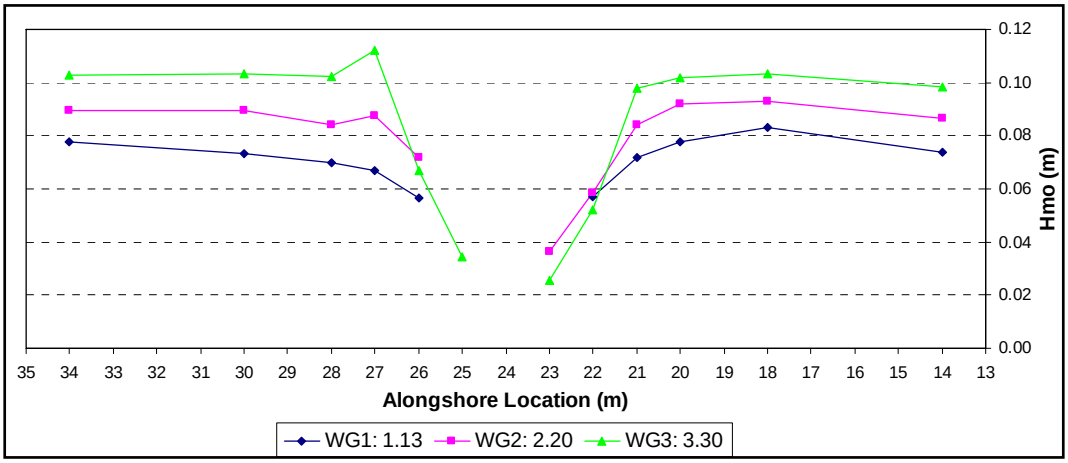

Figure 122. Distribution of wave height inshore of T-groin, T3C2.

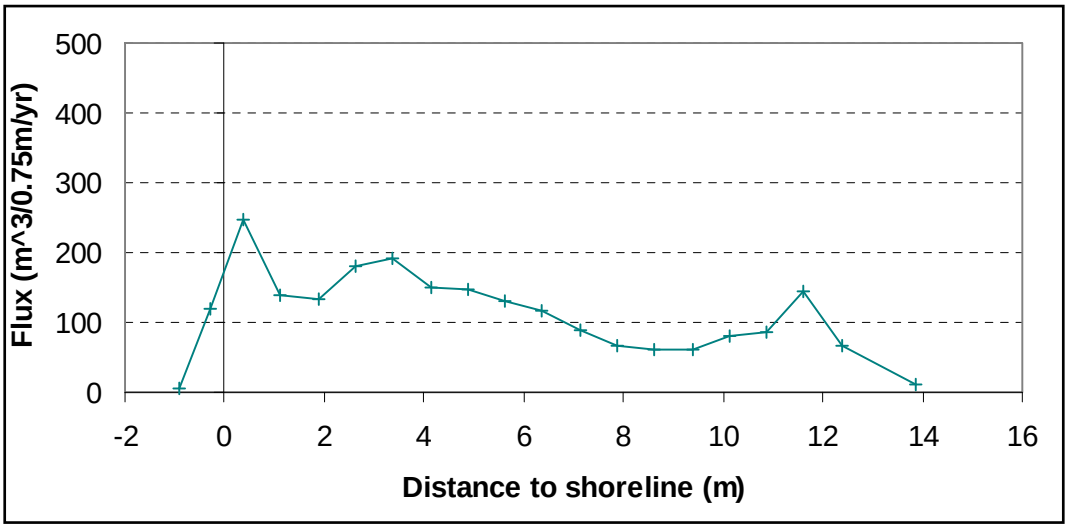

Figure 123. Cross-shore distribution of longshore sediment flux, T3C2.

T3C3

Test 3 Case 3 (T2C3) involved a 180-min run with waves and currents. Waves and currents were sampled at the same 13 cross-shore transects as in T3C1. The updrift beach, from updrift end of the model beach to alongshore position Y = 30 m, was reconstructed to the equilibrium template prior to the run. The data for this run are compiled in seven files as follows:

1. T3C3p.BM (BMAP file, pre-run survey 50 profile lines).
2. T3C3.BM (BMAP file, post-run survey 50 profile lines).
3. T3C3p.xyz (ASCII file, pre-run survey data xyz format).
4. T3C3.xyz (ASCII file, post-run survey data xyz format).

5. T3C3_current_summary.xls (Excel file, current data).
6. T3C3_wave_summary.xls (Excel file, wave data).
7. T3C3_trap_summary.xls (Excel file, sediment trap data).

Figures 124 and 125 provide images of DTM surfaces based on the pre- and post-run survey data sets. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 126. The alongshore distribution of the measured significant wave height inshore of the T-groin is plotted in Figure 127. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 128.

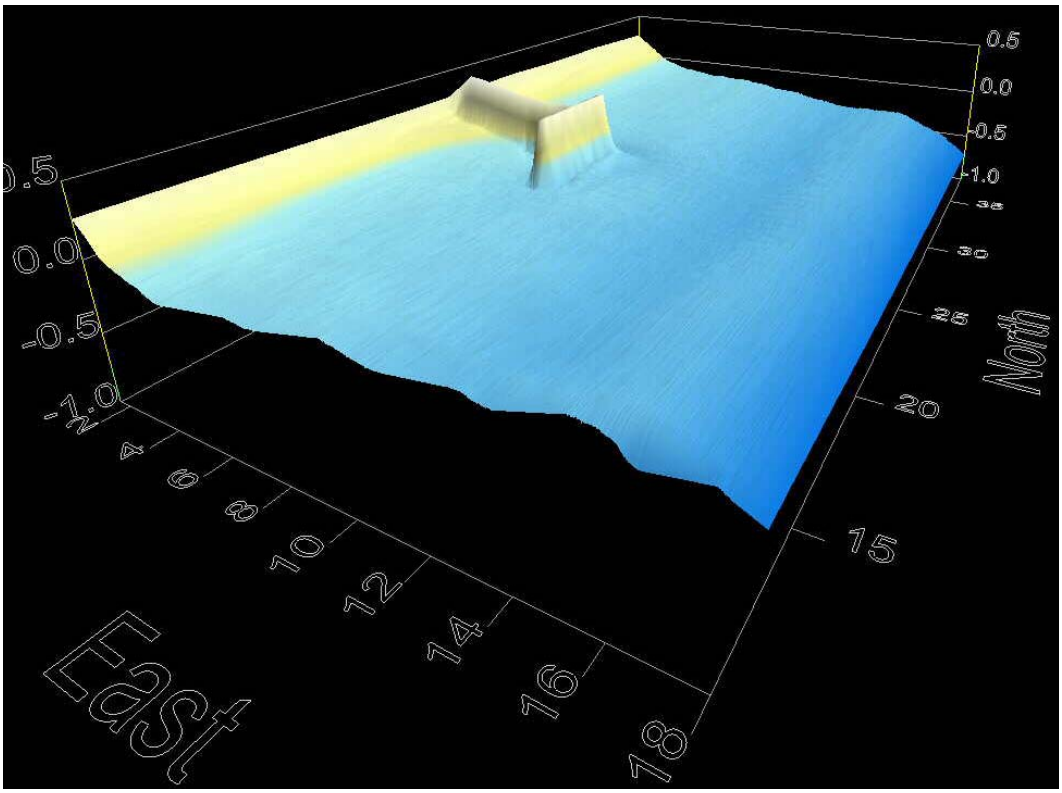

Figure 124. Initial condition model beach, T3C3.

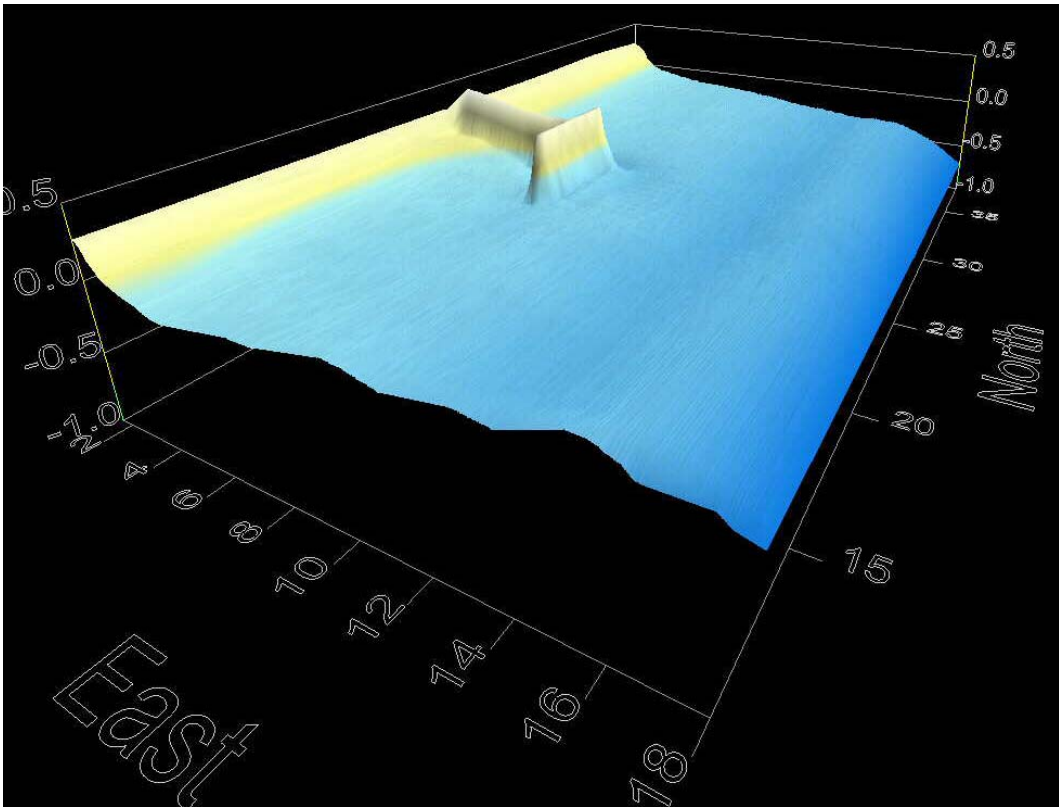

Figure 125. Post-run model beach, T3C3.

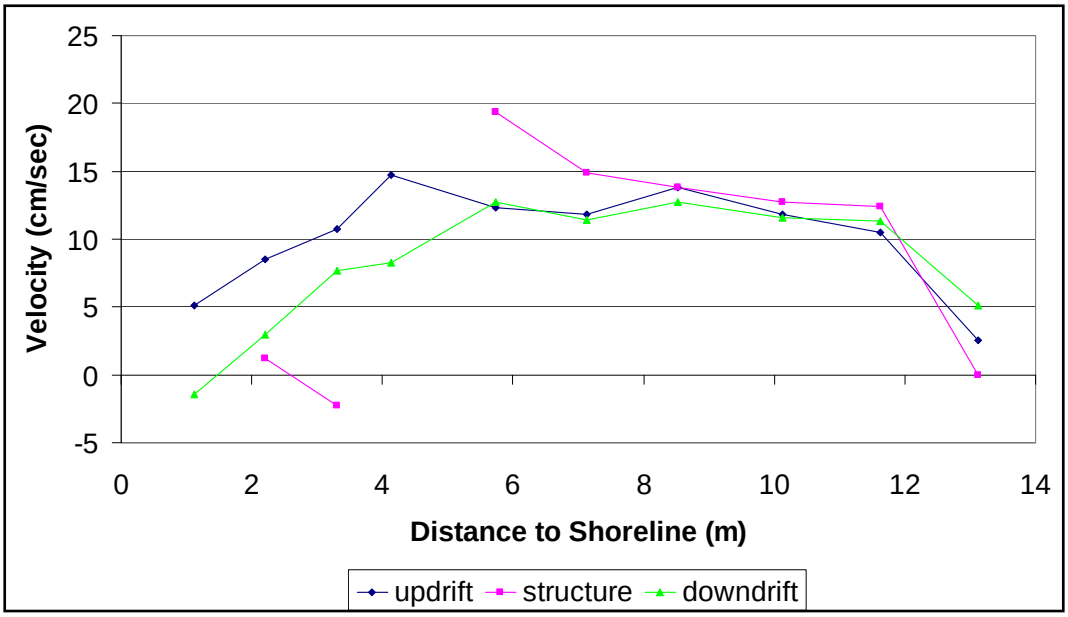

Figure 126. Cross-shore distribution of longshore current, T3C3.

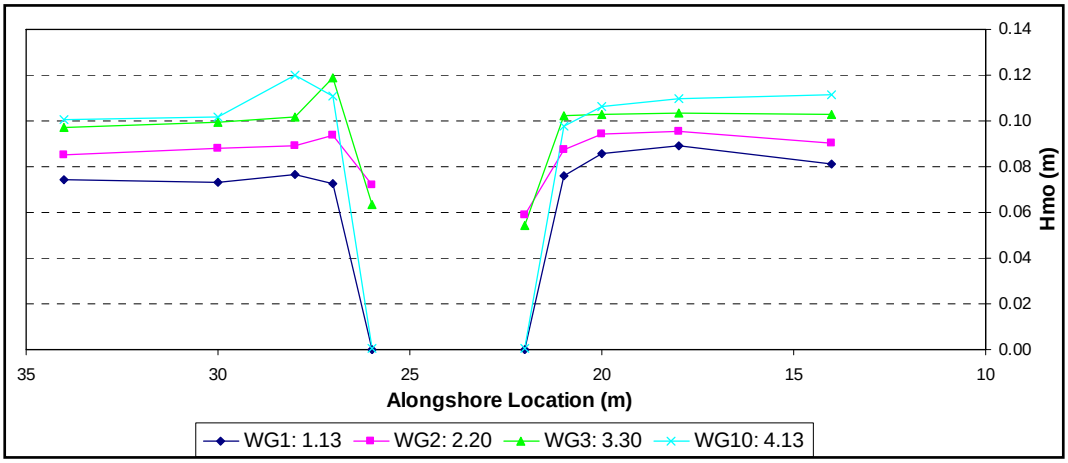

Figure 127. Distribution of wave heights inshore of T-groin, T3C3.

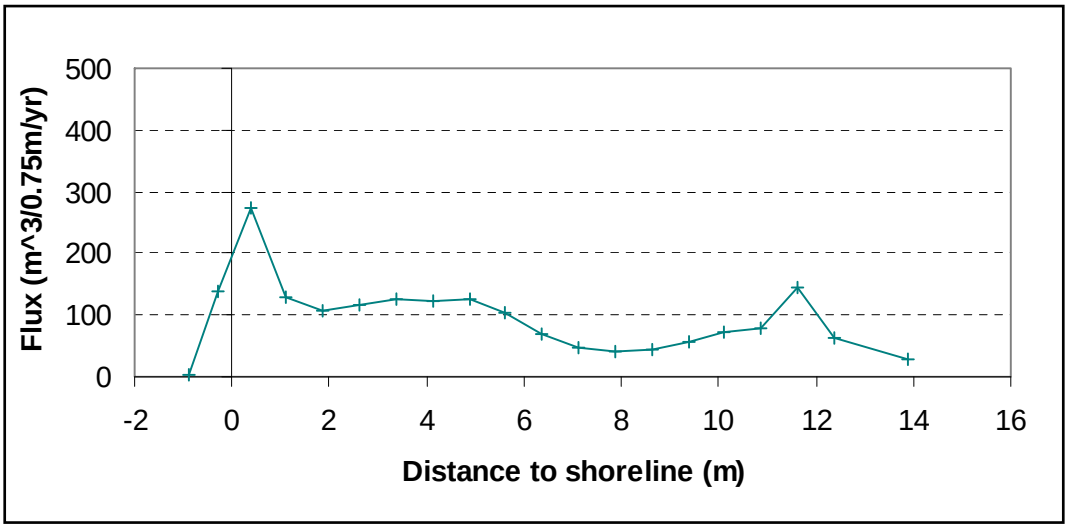

Figure 128. Cross-shore distribution of longshore sediment flux, T3C3.

T3C4

Test 3 Case 4 (T3C4) involved a 180-min run with waves and currents. Waves and currents were sampled at the same 13 cross-shore transects as in T3C1. The data for this run are compiled in five files as follows:

1. T3C4.BM (BMAP file, post-run survey 54 profile lines).
2. T3C4.xyz (ASCII file, post-run survey data xyz format).
3. T3C4_current_summary.xls (Excel file, current data).
4. T3C4_wave_summary.xls (Excel file, wave data).
5. T3C4_trap_summary.xls (Excel file, sediment trap data).

Figure 129 provides a DTM surface based on the post-run survey data. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 130. The alongshore distribution of the measured significant wave height inshore of the T-groin is plotted in Figure 131. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 132.

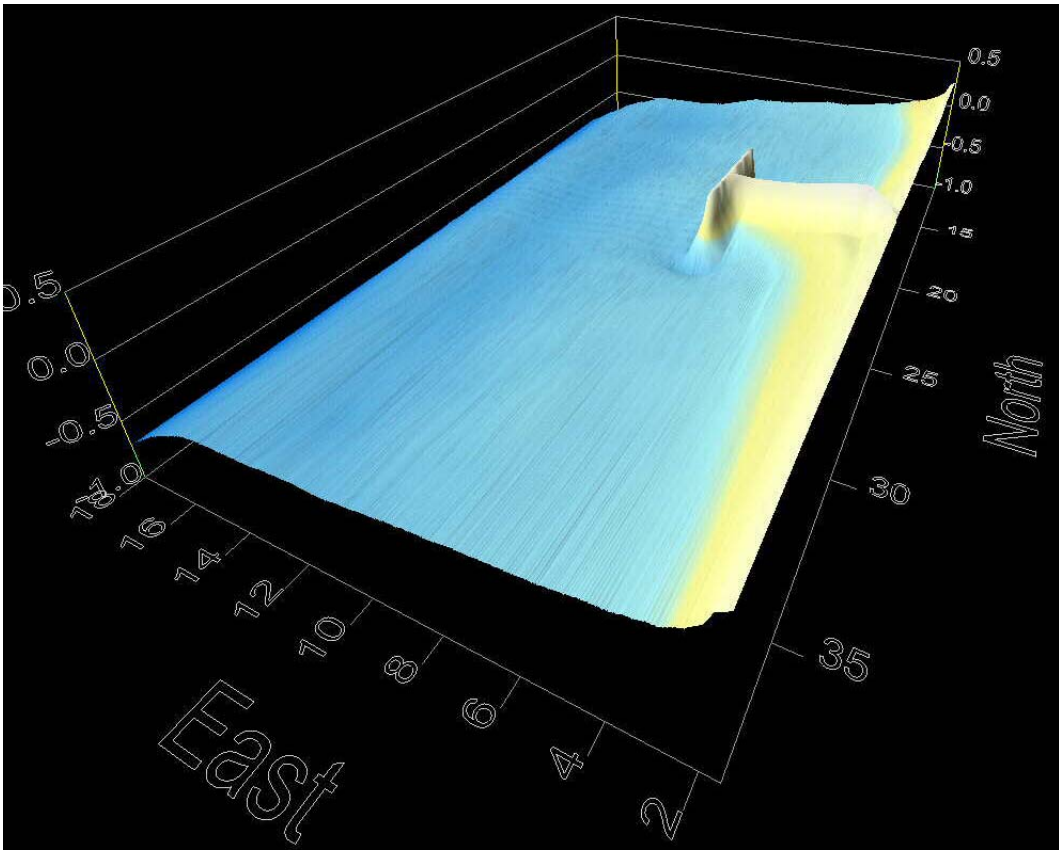

Figure 129. Post-run model beach, T3C4.

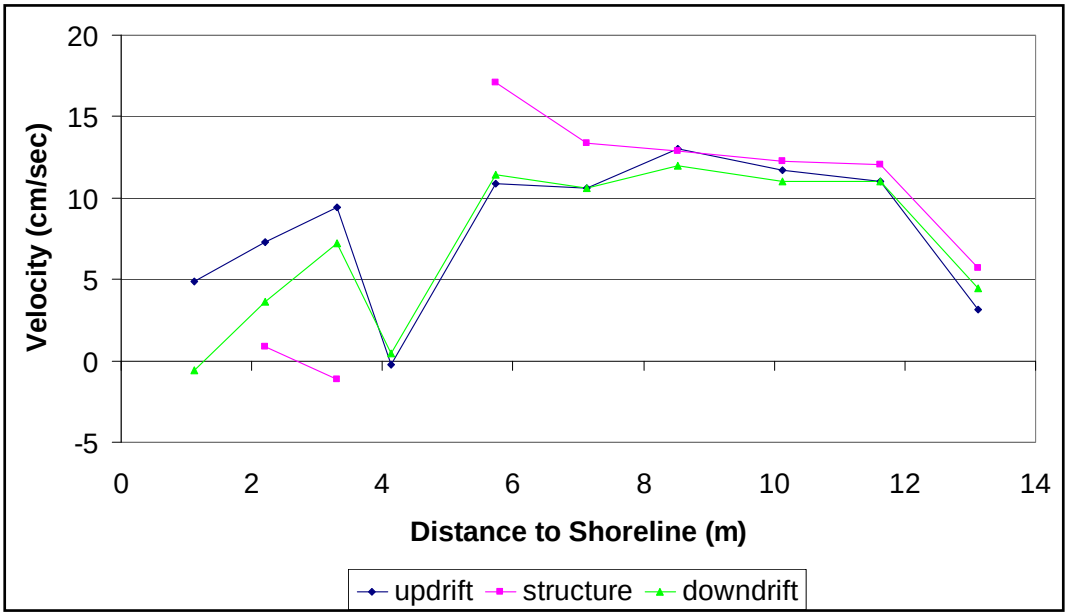

Figure 130. Cross-shore distribution of longshore current, T3C4.

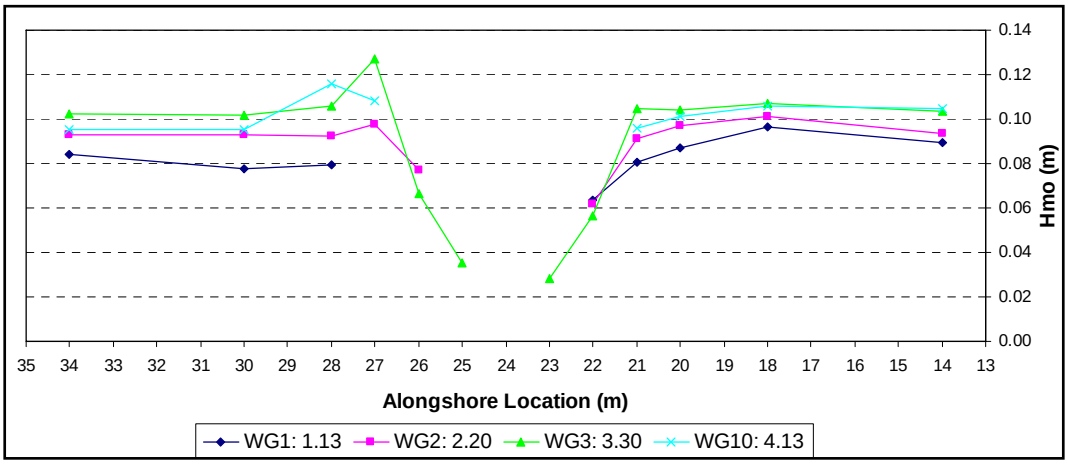

Figure 131. Distribution of wave height inshore of T-groin, T3C4.

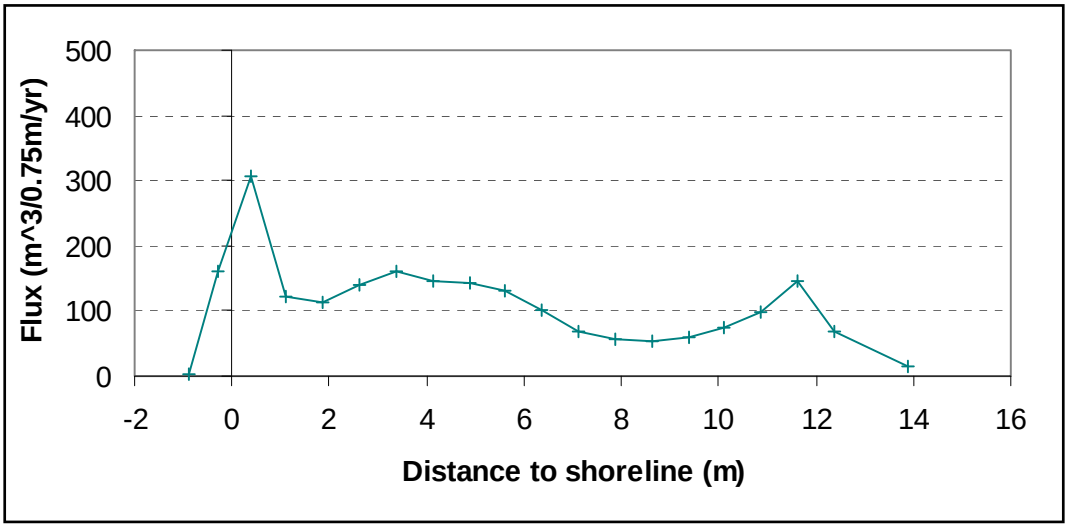

Figure 132. Cross-shore distribution of longshore sediment flux, T3C4.

T3C5

Test 3 Case 5 (T3C5) involved a 180-min run with waves and currents. Waves and currents were sampled at the same 13 cross-shore transects as in T3C1. The updrift beach, from the updrift end of the model beach to alongshore position Y = 30 m, was reconstructed to the equilibrium template prior to the run. The data for this run are compiled in seven files as follows:

1. T3C5p.BM (BMAP file, pre-run survey 53 profile lines).
2. T3C5.BM (BMAP file, post-run survey 55 profile lines).
3. T3C5p.xyz (ASCII file, pre-run survey data xyz format).
4. T3C5.xyz (ASCII file, post-run survey data xyz format).
5. T3C5_current_summary.xls (Excel file, current data).
6. T3C5_wave_summary.xls (Excel file, wave data).
7. T3C5_trap_summary.xls (Excel file, sediment trap data).

Figures 133 and 134 provide images of a DTM surface based on the pre- and post-run survey data. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 135. The alongshore distribution of the measured significant wave height inshore of the T-groin is plotted in Figure 136. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 137.

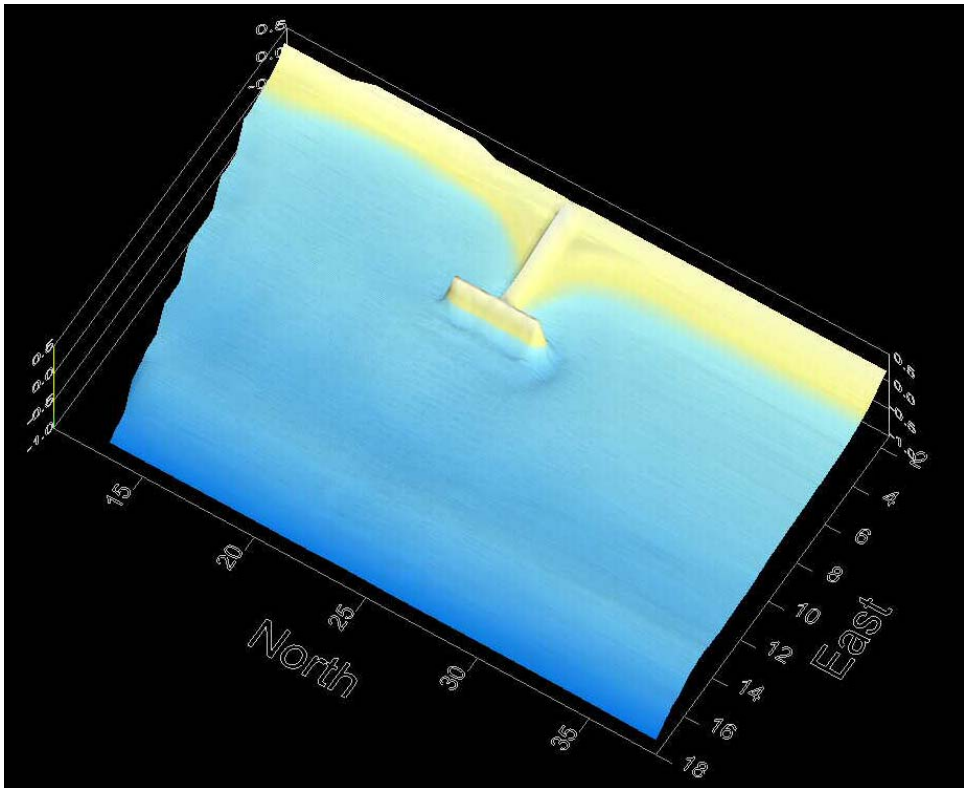

Figure 133. Pre-run model beach, T3C5.

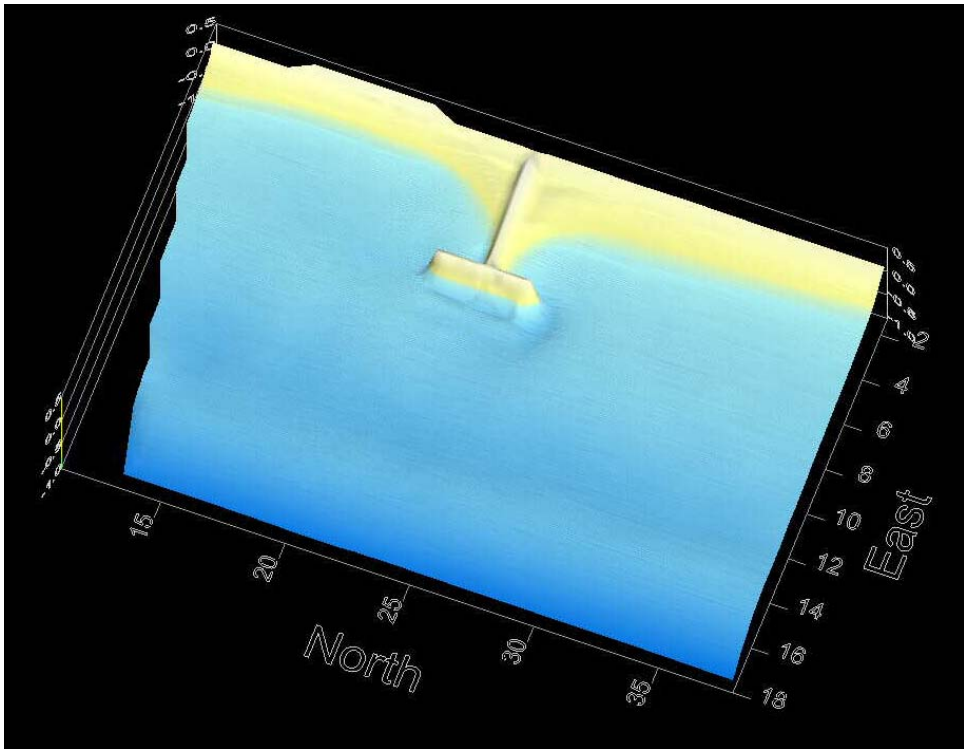

Figure 134. Post-run model beach, T3C5.

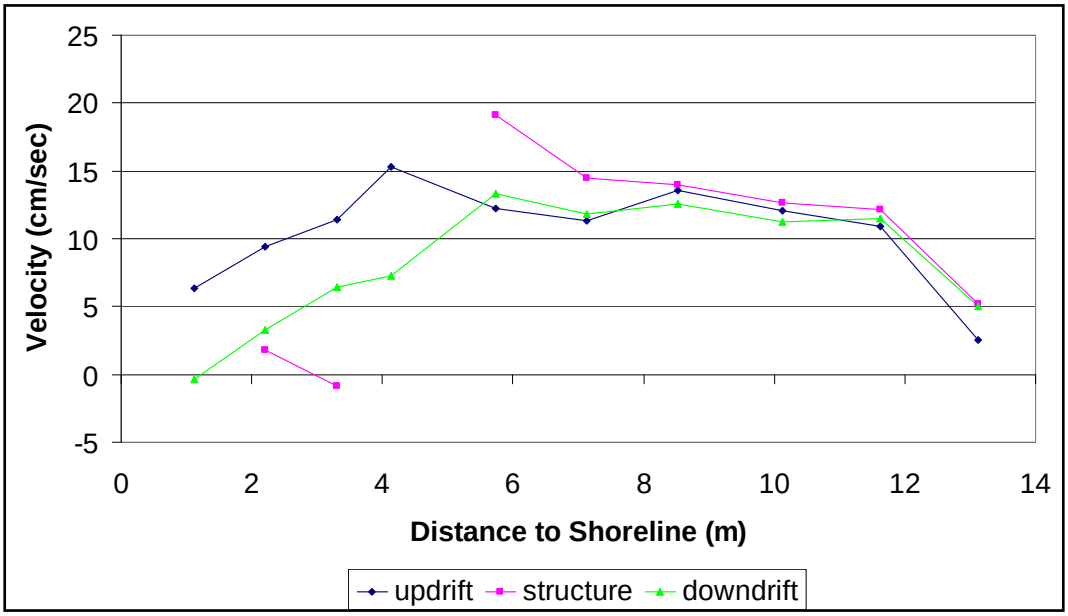

Figure 135. Cross-shore distribution of longshore current, T3C5.

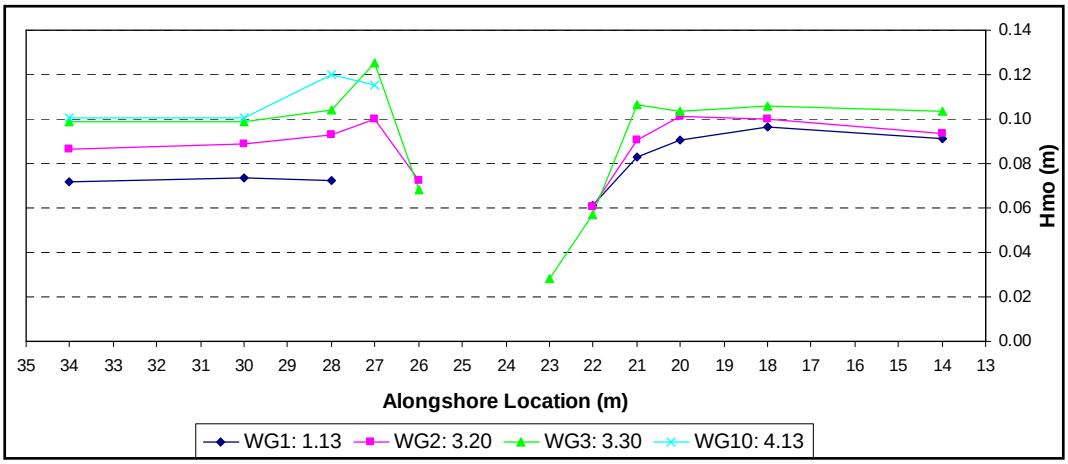

Figure 136. Distribution of wave height inshore of T-groin, T3C5.

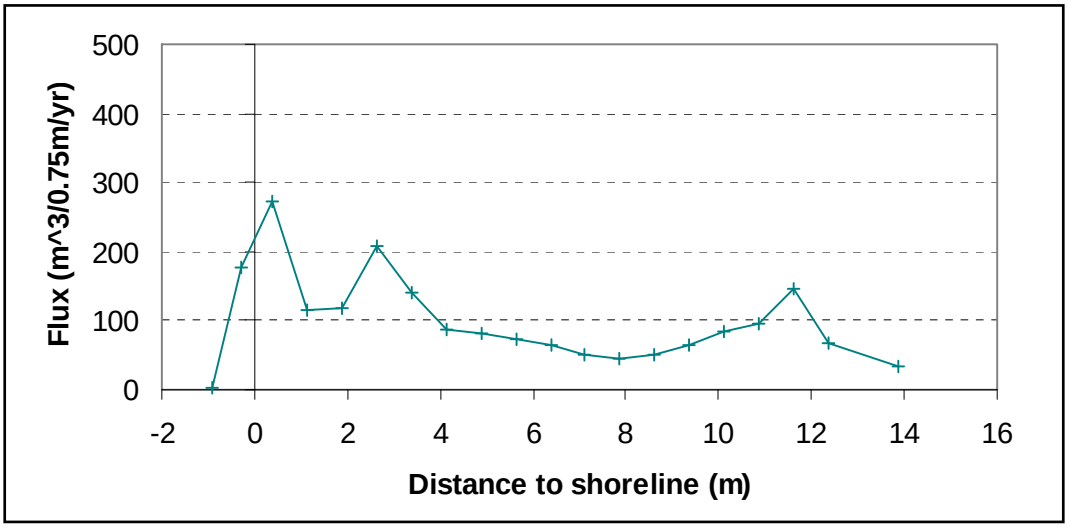

Figure 137. Cross-shore distribution of lonshore sediment flux, T3C5.

T3C6

Test 3 Case 6 (T3C6) involved a 180-min run with waves and currents. Waves and currents were sampled at the same 13 cross-shore transects as in T3C1. The data for this run are compiled in five files as follows:

1. T3C6.BM (BMAP file, post-run survey 54 profile lines).
2. T3C6.xyz (ASCII file, post-run survey data xyz format).
3. T3C6_current_summary.xls (Excel file, current data).
4. T3C6_wave_summary.xls (Excel file, wave data).
5. T3C6_trap_summary.xls (Excel file, sediment trap data).

Figure 138 provides a DTM surface based on the post-run survey data. The cross-shore distribution of the longshore current updrift, at the structure, and downdrift of the structure is plotted in Figure 139. The alongshore distribution of the measured significant wave height inshore of the T-groin is plotted in Figure 140. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 141.

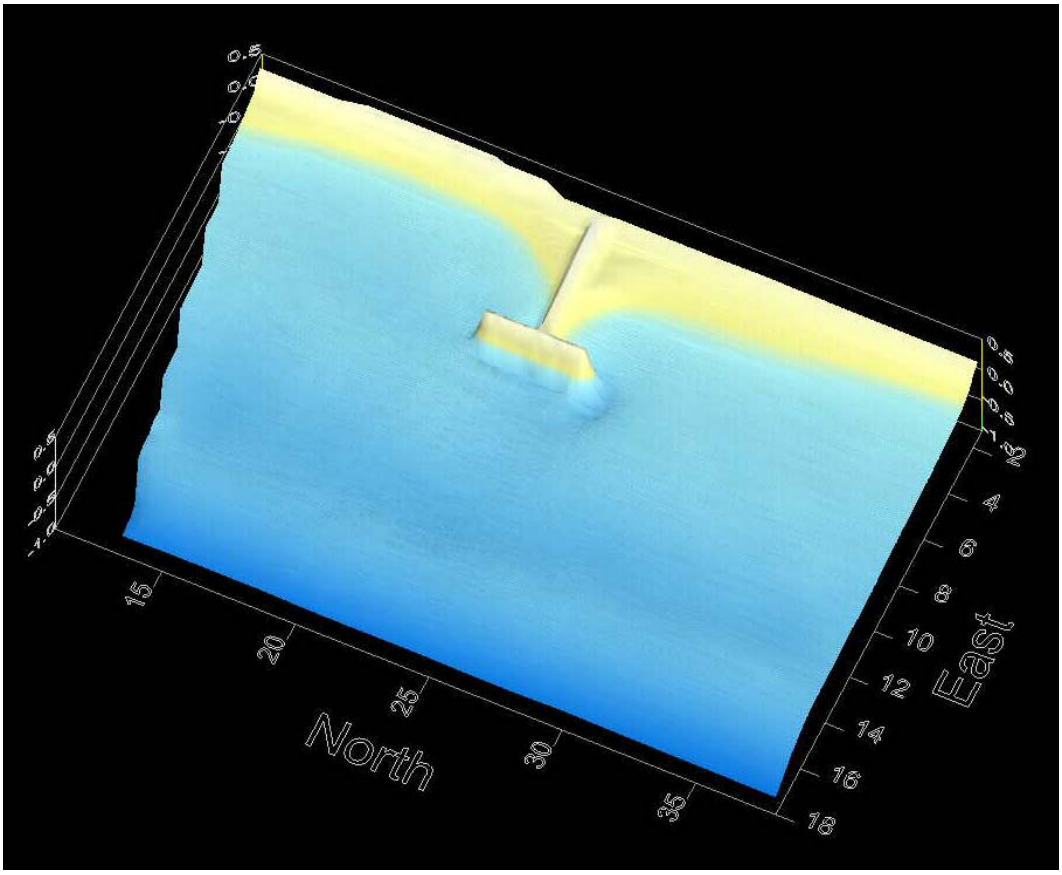

Figure 138. Post-run model beach, T3C6.

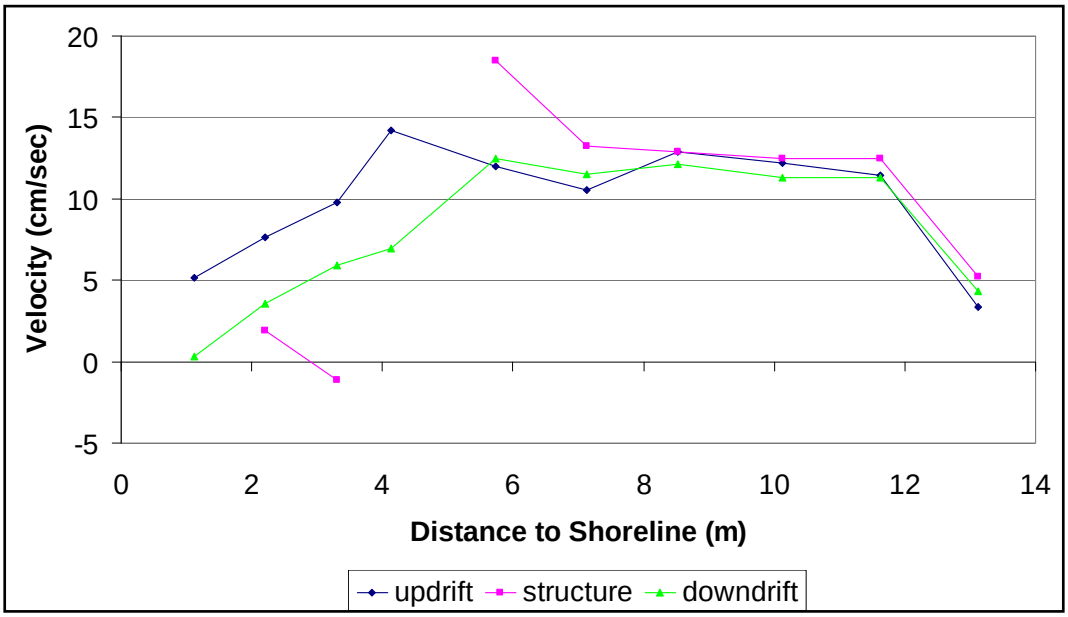

Figure 139. Cross-shore distribution of longshore current, T3C6.

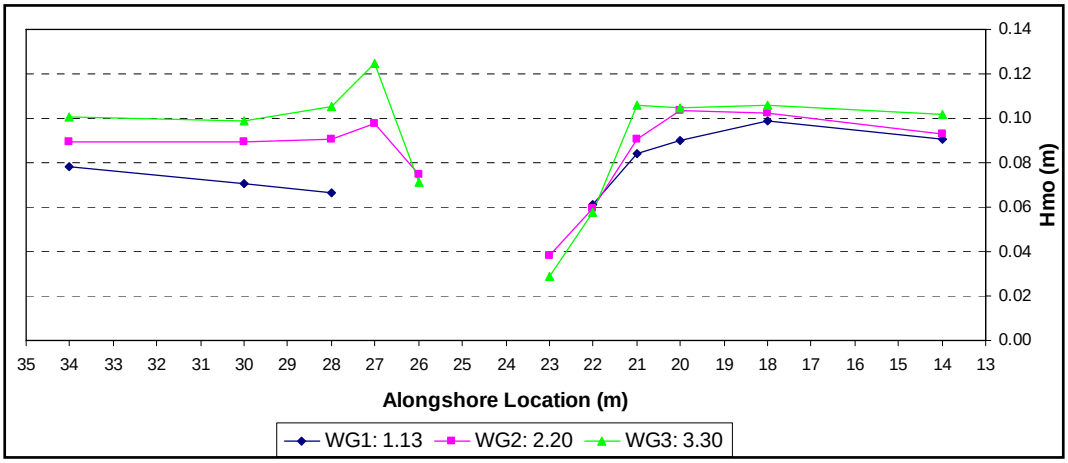

Figure 140. Distribution of wave height inshore of T-groin, T3C6.

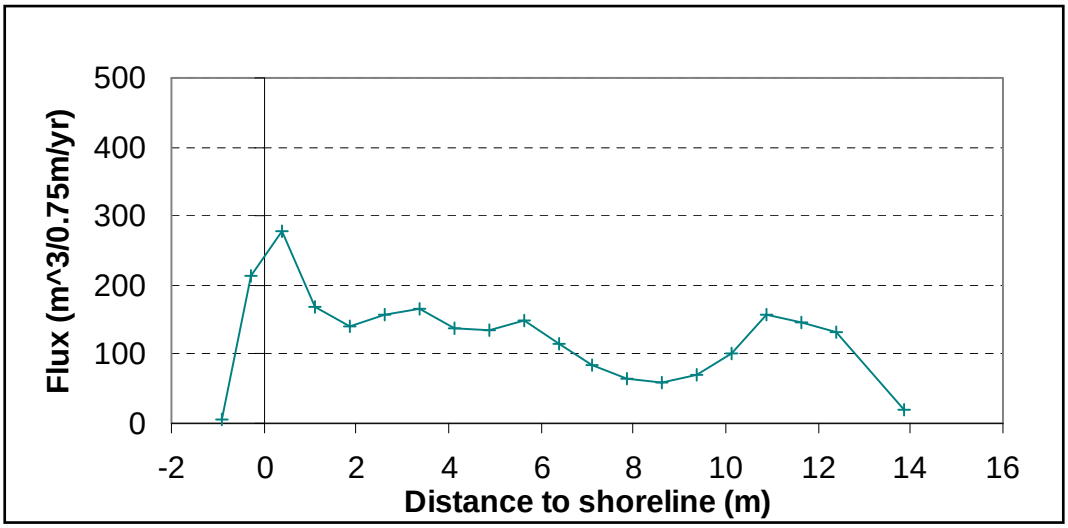

Figure 141. Cross-shore distribution of longshore sediment flux, T3C6.

5 Test 4 Experiments

The Test 4 experiments were performed to assemble additional data sets for testing and validation of numerical model algorithms for development of tombolos in the lee of detached breakwaters, beyond those provided by Tests 1 and 2. Whereas Tests 1 and 2 were conducted with a 4-m-long detached breakwater positioned 4 m offshore of the initial shoreline, the Test 4 experiments were conducted with a 3-m-long detached breakwater positioned 1.5 m offshore. These experiments were executed in a series of four runs of approximately 180 min each on a natural beach with a 3-m-long detached breakwater positioned between alongshore position Y = 27.5 and Y = 24.5 and located 1.5 m offshore of the initial shoreline (Figure 3). In all of the Test 4 runs, the estimated wave-generated longshore flux of water was recirculated from the downstream end to the upstream end of the model beach using the LSTF's external recirculation system.

Breakwater construction

A nearshore rubble-mound detached breakwater was constructed in the LSTF model beach. The breakwater was positioned approximately between alongshore position Y = 27 m and Y = 24 m and at cross-shore position X = 4.5 m (1.5 m offshore of the initial shoreline position at X = 3 m). The movable bed sand beach was excavated down to the concrete bed and two rows of eight concrete blocks were laid down to form the foundation of the breakwater. The area around the breakwater foundation was backfilled including the voids in the concrete blocks and filter cloth was laid over the breakwater foundation (Figure 142). An approximately 12-cm-deep trench was dug around the breakwater foundation and the edges of the filter cloth were placed in the trench and backfilled. A single row of eight concrete blocks was placed on top of the filter cloth, and the voids in the blocks were filled with sand (Figure 143). The concrete block breakwater core was covered with a single layer of riprap stone to complete construction of the nearshore breakwater (Figures 144 and 145).

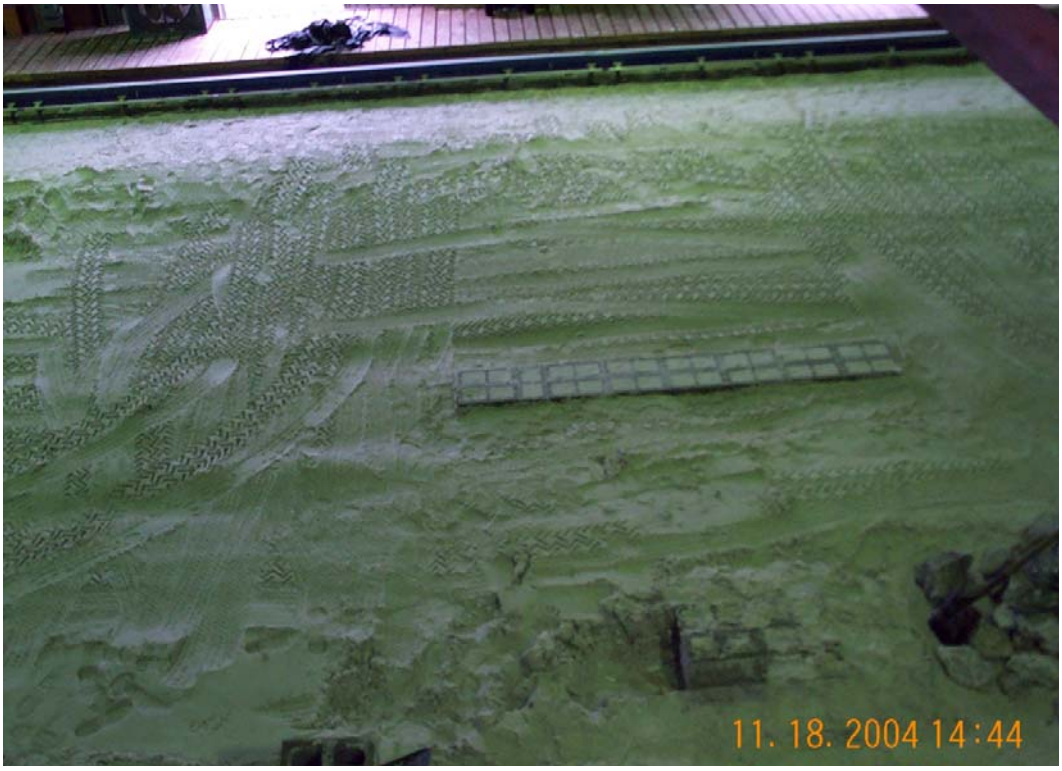

Figure 142. Breakwater foundation and core.

Figure 143. Nearshore breakwater with filter cloth covering foundation layer and second row of sand-filled blocks.

Figure 144. Completed nearshore breakwater structure in LSTF model beach.

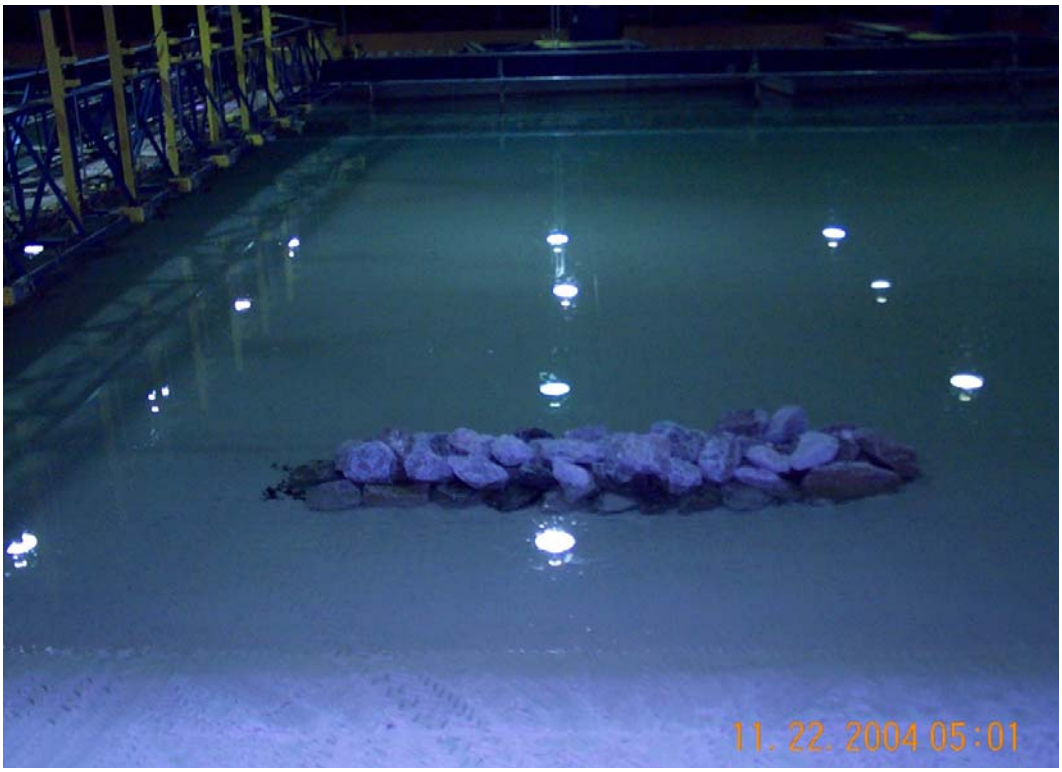

Figure 145. Nearshore breakwater in filled LSTF at operating water level.

T4C1

Test 4 Case 1 (T4C1) involved a 180-min run with waves and currents. Waves and currents were sampled at 14 cross-shore transects (alongshore positions 14, 18, 34, and at 1-m intervals between alongshore position 20 and 30). The data for this run are compiled in seven files as follows:

1. T4C1p.BM (BMAP file, pre-run survey 52 profile lines).
2. T4C1.BM (BMAP file, post-run survey 51 profile lines).
3. T4C1p.xyz (ASCII file, pre-run survey data xyz format).
4. T4C1.xyz (ASCII file, post-run survey data xyz format).
5. T4C1_current_summary.xls (Excel file, current data).
6. T4C1_wave_summary.xls (Excel file, wave data).
7. T4C1_trap_summary.xls (Excel file, sediment trap data).

Figures 146 and 147 provide images of DTMs based on the pre- and post-run survey data sets. Note that for this experiment a tombolo was formed during the first 3-hr run as opposed to after 24 hr of waves and currents in the Test 1 experiments. The average measured cross-shore distribution of the longshore current in three regions, updrift of the structure (measurements taken at Y = 28, 29, 30, and 34), at the structure (measurements taken at Y = 24, 25, 26, and 27), and downdrift of the structure (measurements taken at Y = 14, 18, and 20 through 23), is plotted in Figure 148. The alongshore distribution of the measured significant wave height inshore and offshore of the breakwater is plotted in Figure 149. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 150.

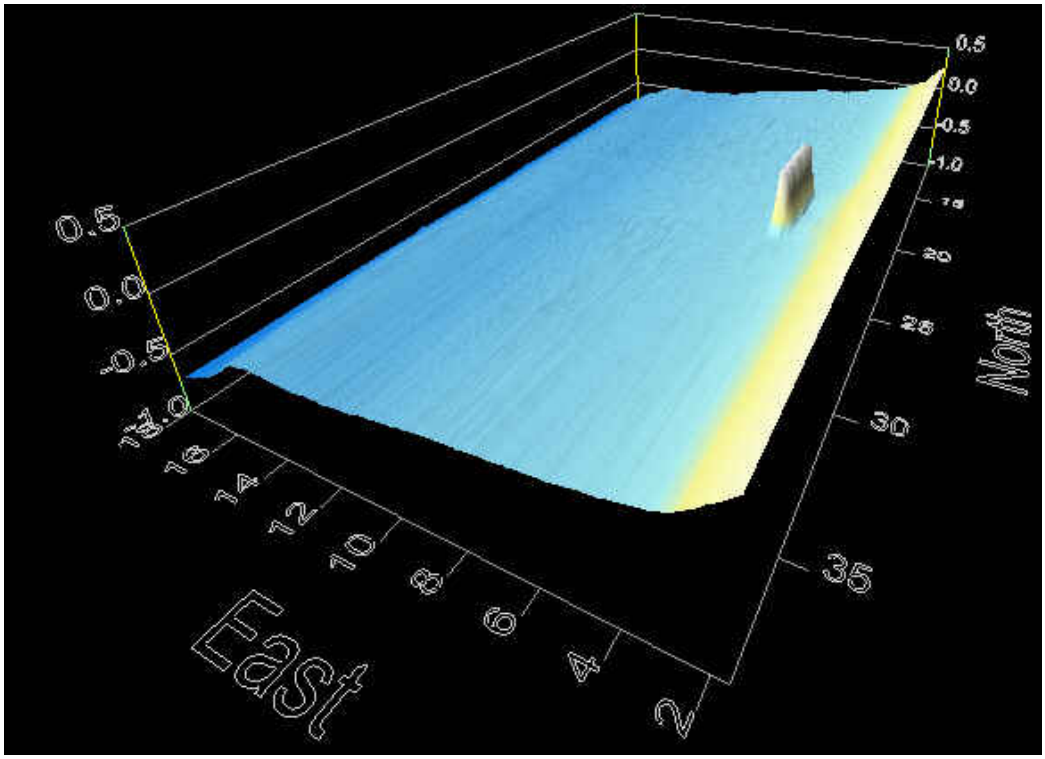

Figure 146. Initial condition model beach, T4C1.

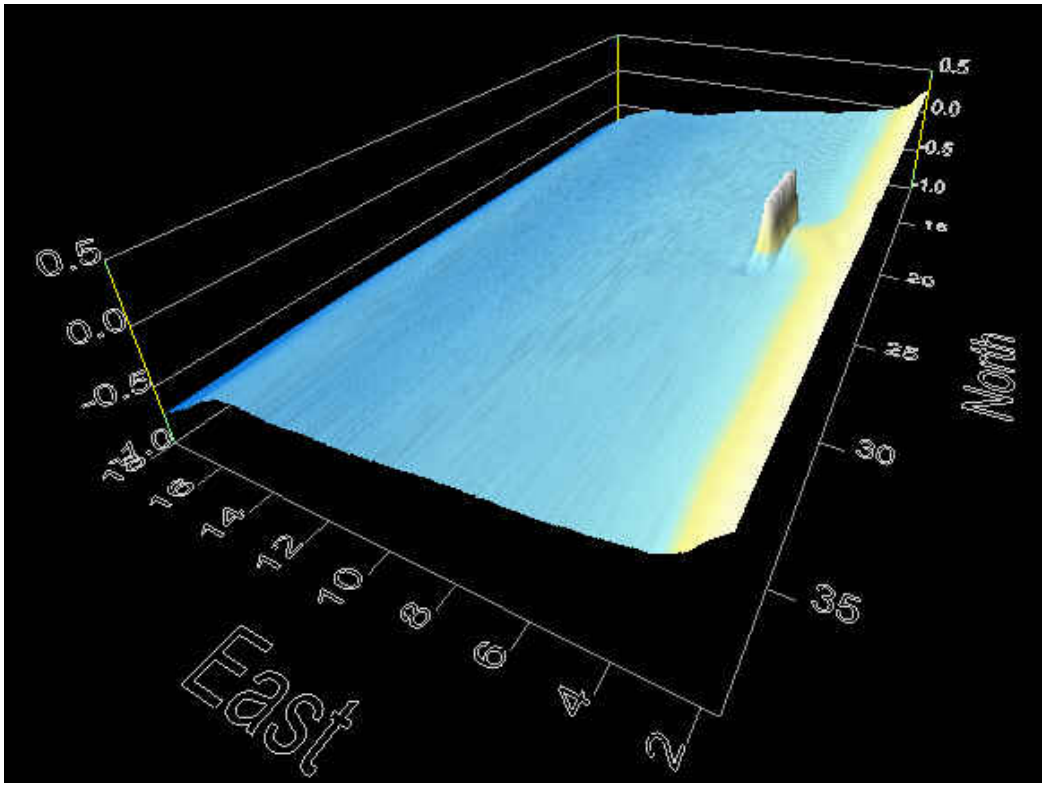

Figure 147. Post-run model beach, T4C1.

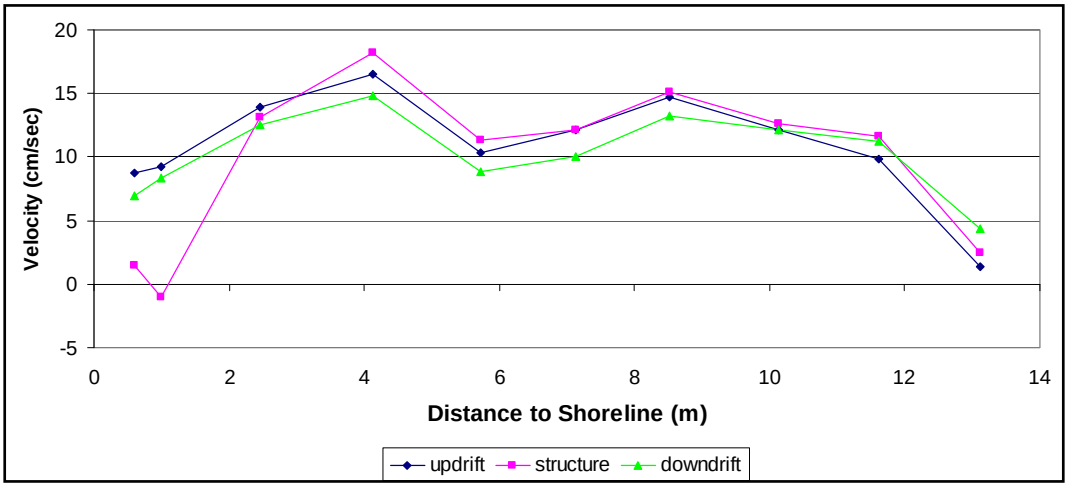

Figure 148. Cross-shore distribution of longshore current, T4C1.

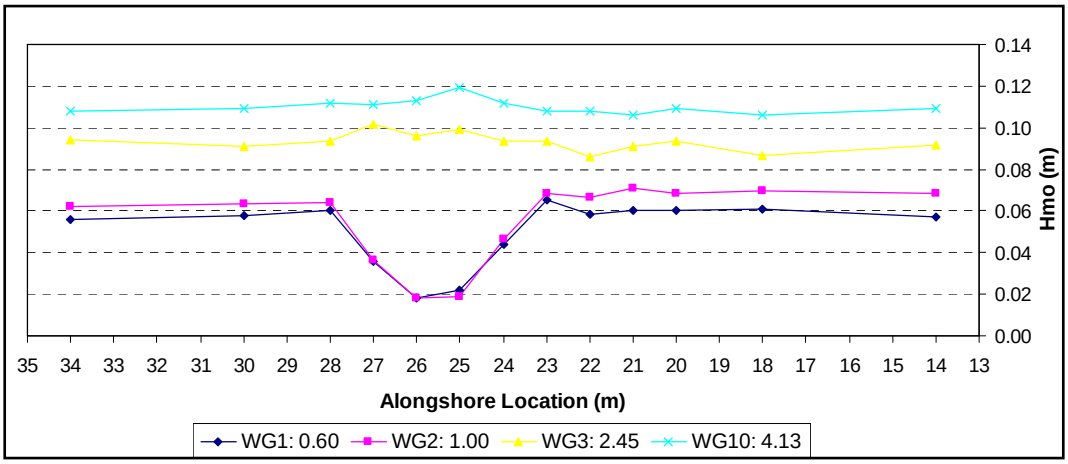

Figure 149. Alongshore distribution of wave height, T4C1.

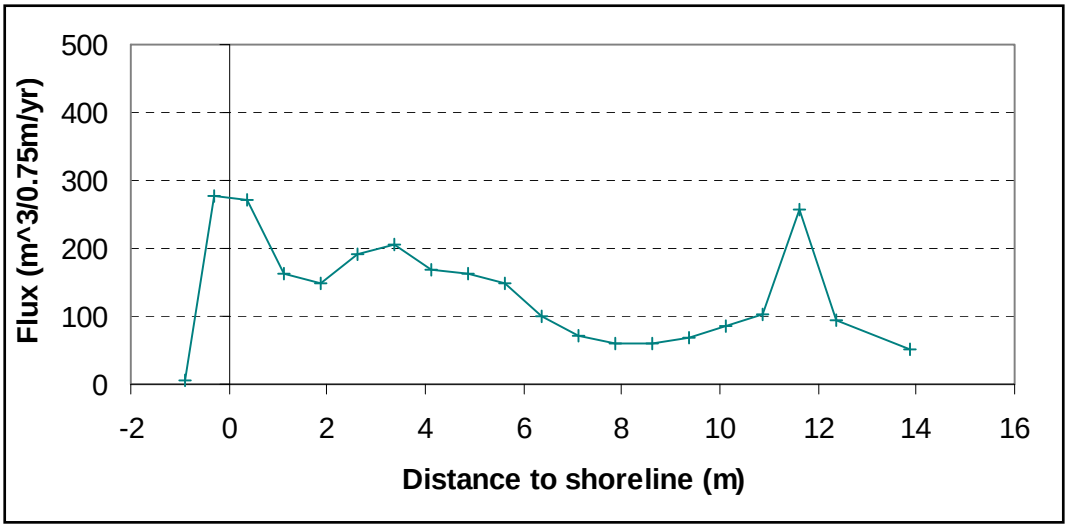

Figure 150. Cross-shore distribution of longshore sediment flux, T4C1.

T4C2

Test 4 Case 2 (T4C2) involved a 181-min run with waves and currents. Waves and currents were sampled at the same 14 cross-shore transects as in T4C1. The data for this run are compiled in five files as follows:

1. T4C2.BM (BMAP file, post-run survey 54 profile lines).
2. T4C2.xyz (ASCII file, post-run survey data xyz format).
3. T4C2_current_summary.xls (Excel file, current data).
4. T4C2_wave_summary.xls (Excel file, wave data).
5. T4C2_trap_summary.xls (Excel file, sediment trap data).

A DTM surface based on the post-run survey data is plotted in Figure 151. The cross-shore distribution of the longshore current updrift and downdrift of the structure is plotted in Figure 152. The alongshore distribution of the measured significant wave height is plotted in Figure 153. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 154.

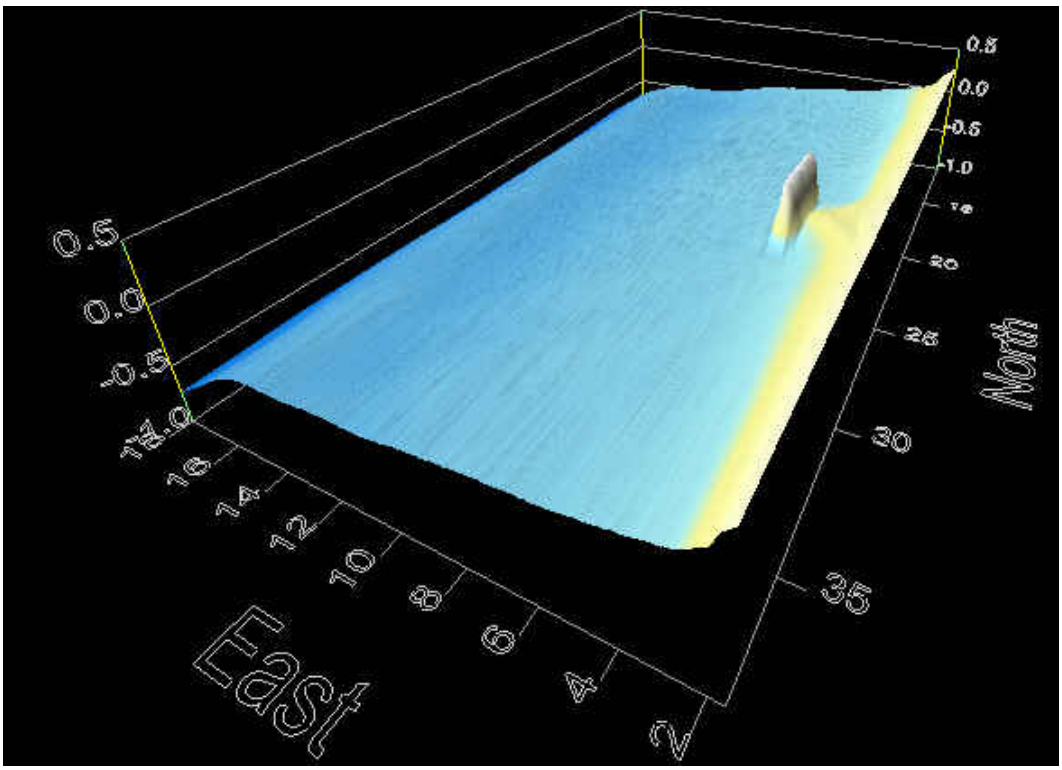

Figure 151. Post-run model beach, T4C2.

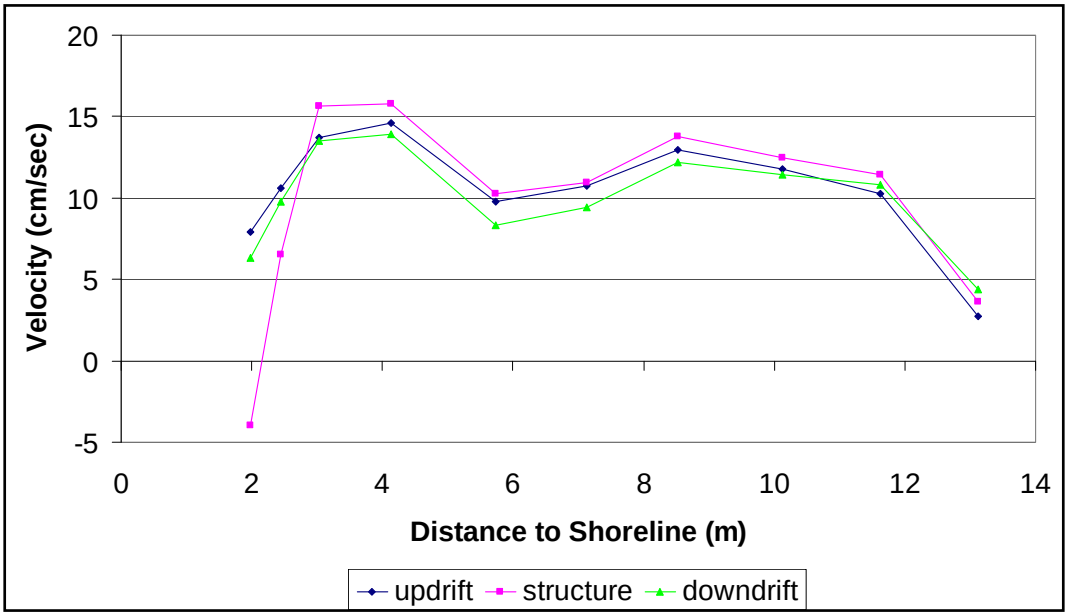

Figure 152. Cross-shore distribution of longshore current, T4C2.

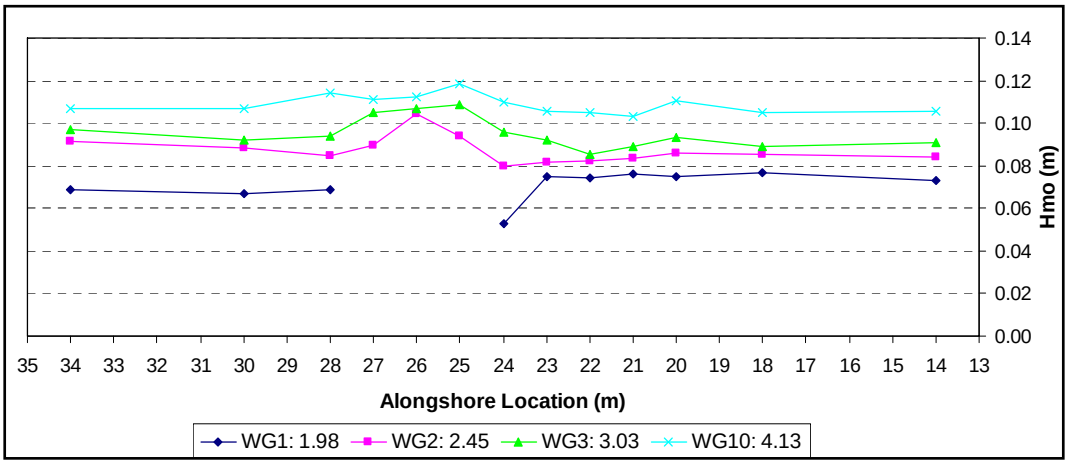

Figure 153. Alongshore distribution of wave height, T4C2.

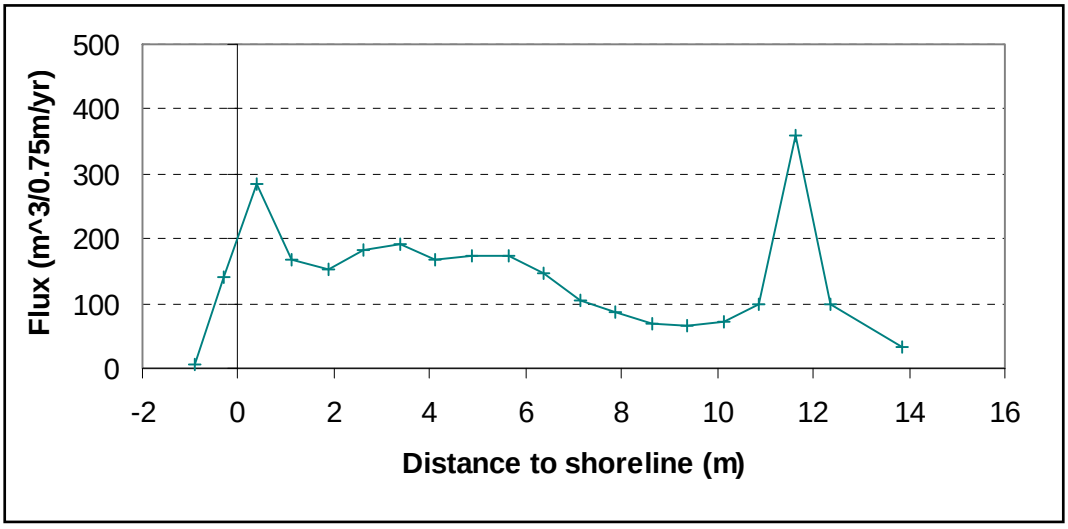

Figure 154. Cross-shore distribution of longshore sediment flux, T4C2.

T4C3

Test 4 Case 3 (T4C3) involved a 180-min run with waves and currents. Waves and currents were sampled at the same 14 cross-shore transects as in T4C1. The updrift beach, from updrift end of the model beach to alongshore position Y = 30.5 m, was reconstructed to the equilibrium template prior to the run. The data for this run are compiled in seven files as follows:

1. T4C3p.BM (BMAP file, pre-run survey 53 profile lines).
2. T4C3.BM (BMAP file, post-run survey 53 profile lines).
3. T4C3p.xyz (ASCII file, pre-run survey data xyz format).
4. T4C3.xyz (ASCII file, post-run survey data xyz format).
5. T4C3_current_summary.xls (Excel file, current data).
6. T4C3_wave_summary.xls (Excel file, wave data).
7. T4C3_trap_summary.xls (Excel file, sediment trap data).

Figures 155 and 156 provide images of DTM surfaces based on the pre- and post-run survey data sets. The cross-shore distribution of the longshore current updrift and downdrift of the structure is plotted in Figure 157. The alongshore distribution of the measured significant wave height is plotted in Figure 158. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 159.

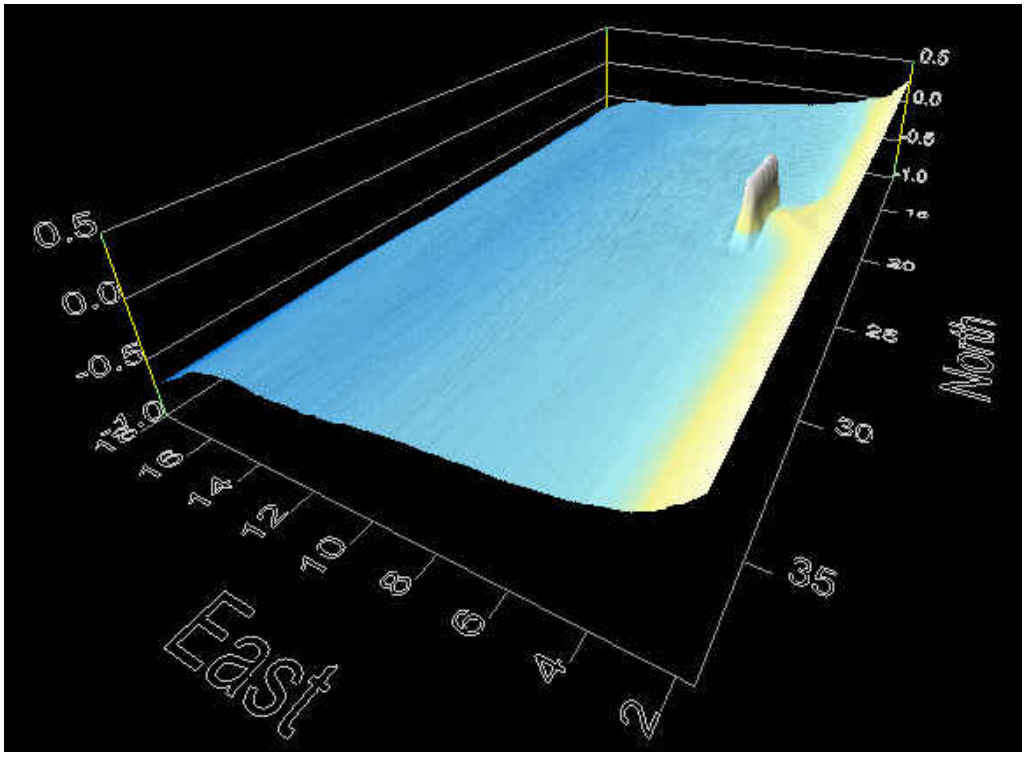

Figure 155. Initial condition model beach, T4C3.

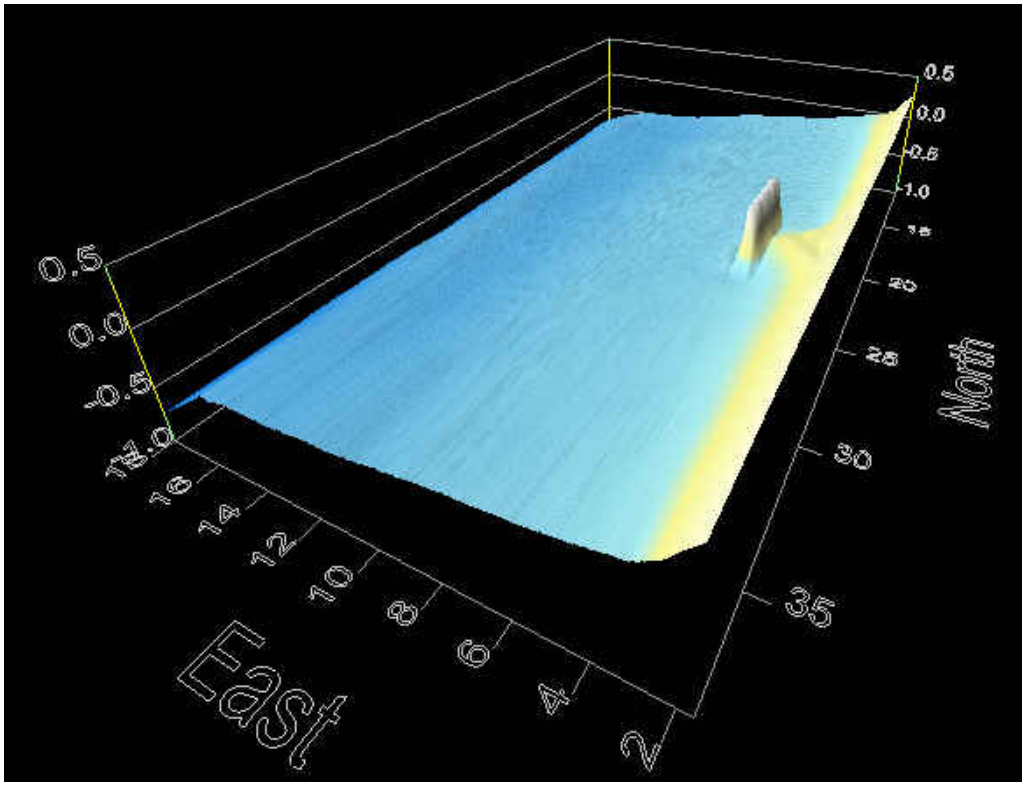

Figure 156. Post-run model beach, T4C3.

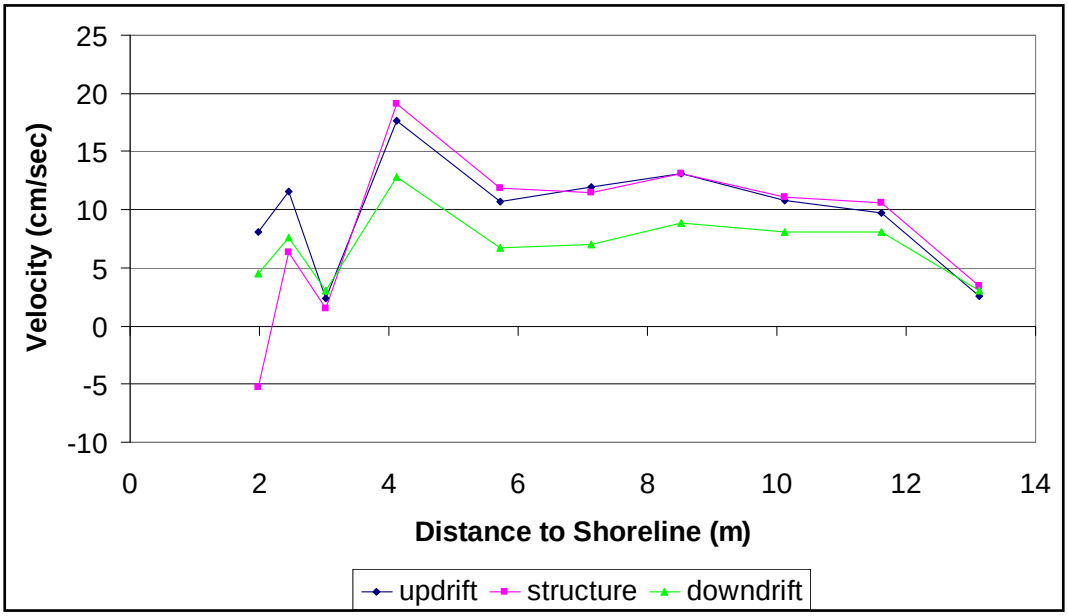

Figure 157. Cross-shore distribution of longshore current, T4C3.

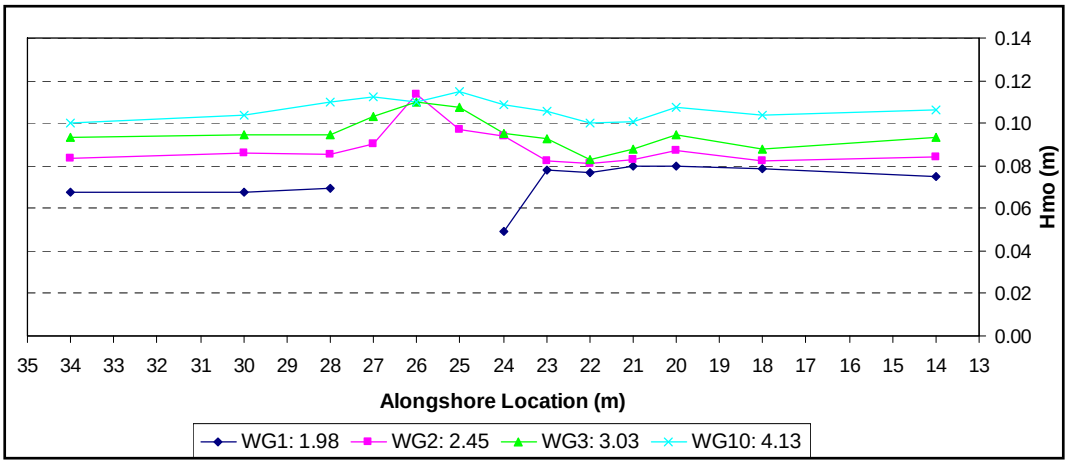

Figure 158. Alongshore distribution of wave heights, T4C3.

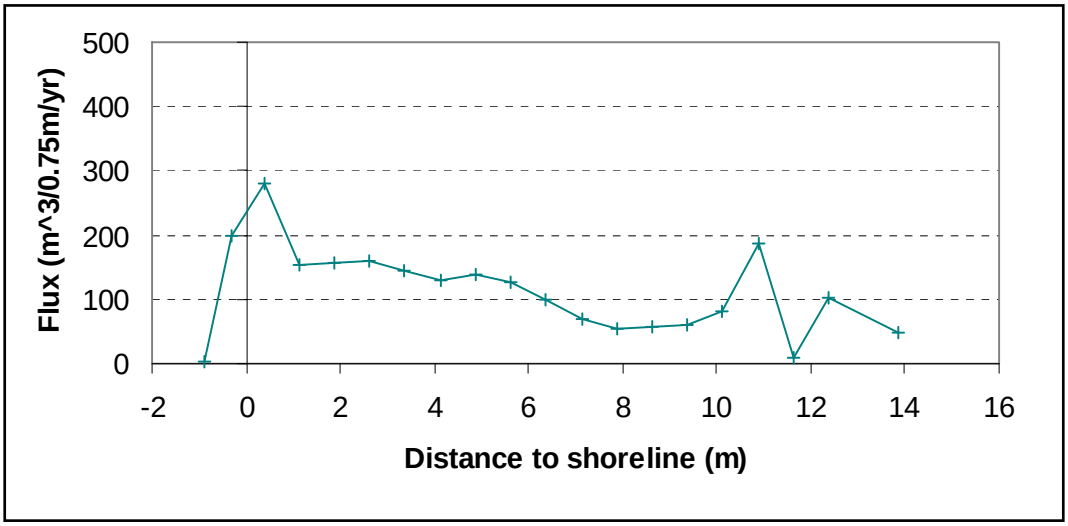

Figure 159. Cross-shore distribution of longshore sediment flux, T4C3.

T4C4

Test 4 Case 4 (T4C4) involved a 180-min run with waves and currents. Waves and currents were sampled at the same 14 cross-shore transects as in T4C1. The data for this run are compiled in five files as follows:

1. T4C4.BM (BMAP file, post-run survey 54 profile lines).
2. T4C4.xyz (ASCII file, post-run survey data xyz format).
3. T4C4_current_summary.xls (Excel file, current data).
4. T4C4_wave_summary.xls (Excel file, wave data).
5. T3C4_trap_summary.xls (Excel file, sediment trap data).

Figure 160 provides a DTM surface based on the post-run survey data. The cross-shore distribution of the longshore current is plotted in Figure 161. The alongshore distribution of the measured significant wave height is plotted in Figure 162. The cross-shore distribution of the measured longshore sediment flux is plotted in Figure 163.

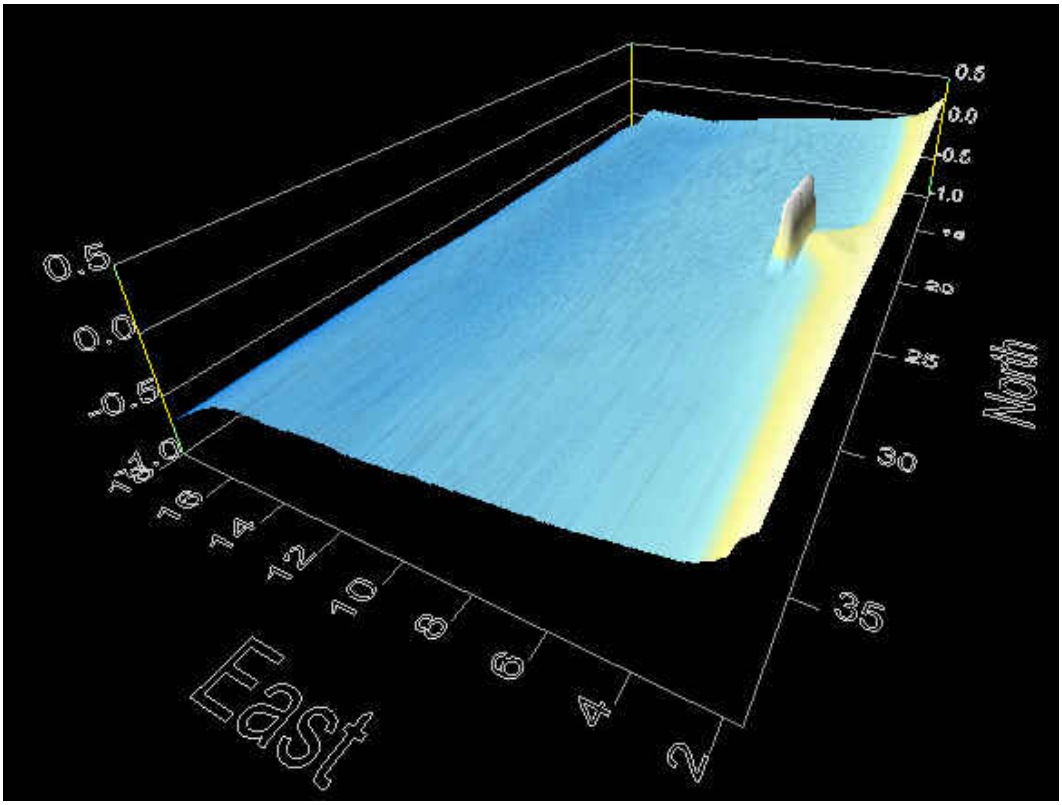

Figure 160. Post-run model beach, T4C4.

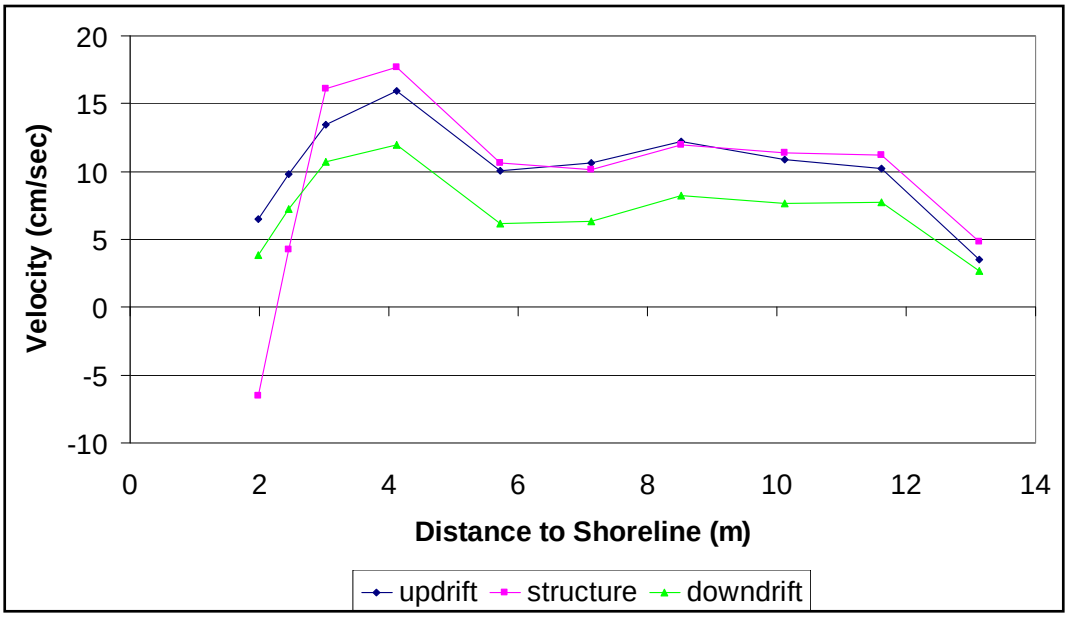

Figure 161. Cross-shore distribution of longshore current, T4C4.

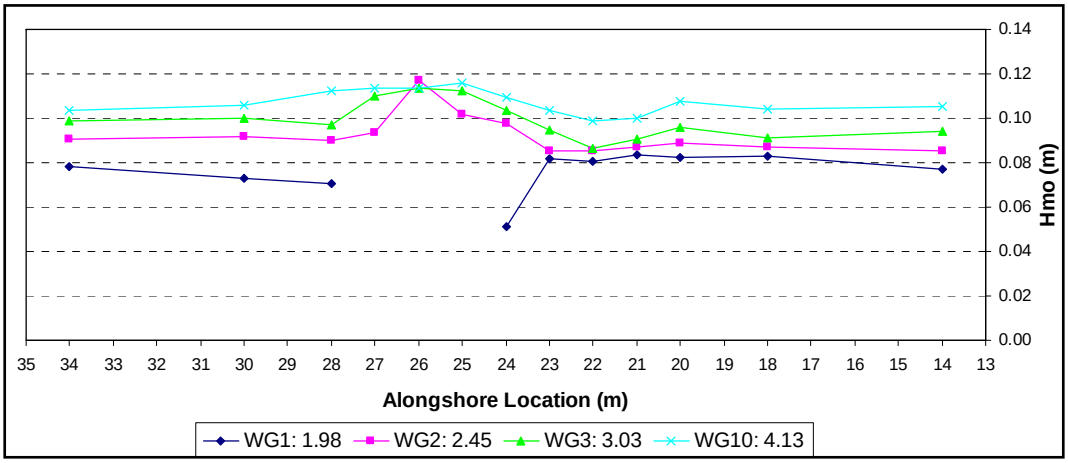

Figure 162. Alongshore distribution of wave height, T4C4.

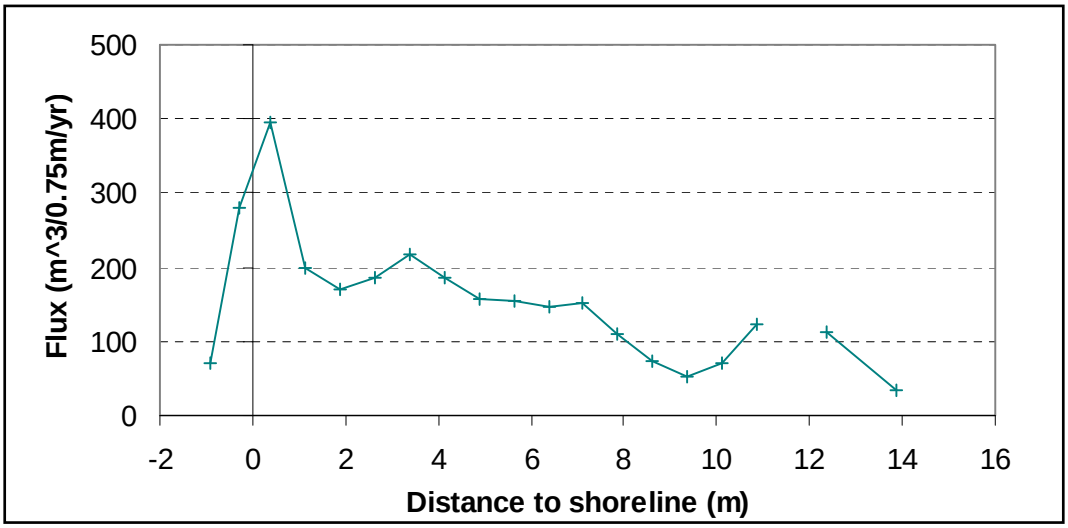

Figure 163. Cross-shore distribution of longshore sediment flux, T4C4.

6 Conclusions

Data from five series of movable bed laboratory experiments have been presented herein. These experiments were conducted in the Large-scale Sediment Transport Facility at the U.S. Army Engineer Research and Development Center, Vicksburg, MS. The data collected from these experiments are being used to improve longshore sand transport relationships under the combined influence of waves and currents and the enhancement of predictive numerical models of beach morphology evolution, in particular, with respect to modeling of tombolo development at detached breakwaters and T-groins. Such conditions often occur on the beaches adjacent to coastal tidal inlets. These data were instrumental in the development and validation of GENESIS-T (Hanson et al. 2006) an enhanced version of GENESIS that allows for continued simulation of shoreline change after tombolo formation at detached breakwaters.

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Hanson, H., M. Larson, N. C. Kraus, M. B. Gravens. 2006. Shoreline response to detached breakwaters and tidal current: Comparison of numerical and physical models. *Proceedings 30th International Conference on Coastal Engineering*, ASCE, 3: 630-3,642.

Hanson, H., M. Larson, and N. C. Kraus. 2001. A new approach to represent tidal currents and bathymetric features in the one-line model concept. *Proceedings Coastal Dynamics '01*, ASCE, 172-181.

Sommerfeld, B., G., J. M. Mason, N. C. Kraus, and M. Larson. 1994. *BFM: Beach Fill Module, Report 1, Beach Morphology Analysis Package (BMAP) – User's Guide*. Coastal and Hydraulics Laboratory Instruction Report CERC-94-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

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To obtain the data sets collected in these experiments contact Mark B. Gravens (*Mark.B.Gravens@erdc.usace.army.mil*) or 601-634-3809.

14. ABSTRACT

Data from five series of movable bed laboratory experiments are presented in this report. These experiments were conducted in the Large-scale Sediment Transport Facility at the U.S. Army Engineer Research and Development Center, Vicksburg, MS. The data collected from these experiments is being used to improve longshore sand transport relationships under the combined influence of waves and currents and the enhancement of predictive numerical models of beach morphology evolution, in particular, with respect to modeling of tombolo development at detached breakwaters and T-groins. These data were instrumental in the development and validation of GENESIS-T, an enhanced version of GENESIS that allows for continued simulation of shoreline evolution after tombolo formation at detached breakwaters.

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